SUMMARY

The subject matter of the present application has been developed in response to the present state of the art, and in particular, in response to the shortcomings associated with damaged hollow bladders, that have not yet been fully solved by currently available techniques. Accordingly, the subject matter of the present application has been developed to provide methods of repairing hollow bladders that overcome at least some of the above-discussed shortcomings of prior art techniques.

The following is a non-exhaustive list of examples, which may or may not be claimed, of the subject matter, disclosed herein.

Disclosed herein is a method of repairing surface damage in an exterior surface of a hollow bladder, made of a cured elastomer. The method comprises placing first strips, made of an uncured elastomer, at least partially within the surface damage in the exterior surface of the hollow bladder in a side-by-side arrangement such that a slit defined between the first strips is positioned over the surface damage. The method also comprises sealing the surface damage, the first strips, and a portion of the exterior surface surrounding the surface damage in a vacuum bag. The method further comprises reducing pressure within the vacuum bag relative to outside the vacuum bag. The method additionally comprises while the pressure within the vacuum bag is reduced, heating the first strips from within the vacuum bag to cure the first strips. The preceding subject matter of this paragraph characterizes example 1 of the present disclosure.

The method further comprises applying a peel ply onto the exterior surface of the hollow bladder away from the surface damage in the exterior surface. The method also comprises placing a caul plate assembly, comprising a caul plate and a breathable release film, onto the exterior surface, over an entirety of the surface damage in the exterior surface, and onto the peel ply such that the breathable release film is interposed between the surface damage and the caul plate and the breathable release film is interposed between the peel ply and the caul plate. The method further comprises placing a heating blanket onto the caul plate assembly. The method additionally comprises sealing the peel ply, the caul plate assembly, and the heating blanket, together with the surface damage, the first strips, and the portion of the exterior surface surrounding the surface damage, in the vacuum bag. The first strips are heated from within the vacuum bag by the heating blanket. The preceding subject matter of this paragraph characterizes example 2 of the present disclosure, wherein example 2 also includes the subject matter according to example 1, above.

bevel. The preceding subject matter of this paragraph characterizes example 9 of the present disclosure, wherein example 9 also includes the subject matter according to any one of examples 6-8, above.

The method further comprises sealing the through-hole along an interior surface of the hollow bladder with a pressure-sensitive sealant tape adhered to the interior surface of the hollow bladder. The preceding subject matter of this paragraph characterizes example 10 of the present disclosure, wherein example 10 also includes the subject matter according to any one of examples 6-9, above.

The method further comprises removing the pressure-sensitive sealant tape from the interior surface of the hollow bladder after the first strips are cured. The preceding subject matter of this paragraph characterizes example 11 of the present disclosure, wherein example 11 also includes the subject matter according to example 10, above.

The method further comprises placing a release film within the through-hole between the second strips and the pressure-sensitive sealant tape. The preceding subject matter of this paragraph characterizes example 12 of the present disclosure, wherein example 12 also includes the subject matter according to any one of examples 10-11, above.

Further disclosed herein is a method of repairing a through-hole in a hollow bladder, made of a cured elastomer, the through-hole extending from an exterior surface of the hollow bladder to an interior surface of the hollow bladder. The method comprises placing strips, made of an uncured elastomer, within the through-hole of the hollow bladder such that a slit defined between the strips is positioned over the through-hole. The method also comprises sealing the through-hole along the interior surface of the hollow bladder with a pressure-sensitive sealant tape adhered to the interior surface of the hollow bladder. The method further comprises reducing a pressure at the exterior surface around the through-hole, to below atmospheric pressure, after the through-hole is sealed along the interior surface with the pressure-sensitive sealant tape. The method additionally comprises curing the strips by heating the strips while the through-hole is sealed along the interior surface by the pressure-sensitive sealant tape and while the pressure at the exterior surface around the through-hole is reduced. The method also comprises removing the pressure-sensitive sealant tape from the interior surface of the hollow bladder after the strips are cured. The preceding subject matter of this paragraph characterizes example 13 of the present disclosure.

The method further comprises inserting the pressure-sensitive sealant tape, from a location exterior to the hollow bladder, through the through-hole and into an interior cavity of the hollow bladder before sealing the through-hole along the interior surface of the hollow

The method further comprises attaching an installation line to the pressure-sensitive sealant tape before the pressure-sensitive sealant tape is inserted through the through-hole and into the interior cavity of the hollow bladder. Sealing the through-hole along the interior surface of the hollow bladder with the pressure-sensitive sealant tape comprises inserting a first portion of the installation line through the through-hole and into the interior cavity along with the pressure-sensitive sealant tape, leaving a second portion of the installation line exteriorly of the hollow bladder after the pressure-sensitive sealant tape is inserted into the interior cavity, and, with the pressure-sensitive sealant tape inserted into the interior cavity, pulling the second portion of the installation line away from the interior cavity to raise the pressure-sensitive sealant tape into adhering contact with the interior surface of the hollow bladder. The preceding subject matter of this paragraph characterizes example 18 of the present disclosure, wherein example 18 also includes the subject matter according to any one of examples 14-17, above.

Attaching the installation line to the pressure-sensitive sealant tape comprises attaching a first end portion to a first location on the pressure-sensitive sealant tape and attaching a second end portion to a second location on the pressure-sensitive sealant tape. The first location is spaced apart from the second location by a distance less than a maximum length of the through-hole. Inserting the first portion of the installation line through the through-hole and into the interior cavity comprises inserting a first portion of the first end portion of the installation line and a first portion of the second end portion of the installation line through the through-hole and into the interior cavity. Leaving a second portion of the installation line exteriorly of the hollow bladder after the pressure-sensitive sealant tape is inserted into the interior cavity comprises leaving a second portion of the first end portion of the installation line and a second portion of the second end portion of the installation line exteriorly of the hollow bladder after the pressure-sensitive sealant tape is inserted into the interior cavity. Pulling the second portion of the installation line away from the interior cavity comprises evenly pulling the second portion of the first end portion and the second portion of the second end portion of the installation line away from the interior cavity. The preceding subject matter of this paragraph characterizes example 19 of the present disclosure, wherein example 19 also includes the subject matter according to example 18, above.

Additionally disclosed herein is a method of repairing surface damage in an exterior surface of a hollow bladder, made of a cured fluoroelastomer. The method comprises placing first strips, made of an uncured fluoroelastomer, at least partially within the surface damage in the exterior surface of the hollow bladder such that a slit defined between the first strips is positioned over the surface damage. The method also discloses reducing a pressure at the

exterior surface, around the surface damage and the first strips, to below atmospheric pressure. The method further discloses, while the pressure at the exterior surface around the surface damage and the first strips is reduced, curing the first strips, by, in order: heating the first strips at a first temperature of 79.4 ℃ (175F) for fifteen minutes, heating the first strips at a second temperature of 85℃ (185F) for ten minutes, heating the first strips at a third temperature of 90.6℃ (195F) for ten minutes, heating the first strips at a fourth temperature of 137.8℃ (280F) for ten minutes, and heating the first strips at a fifth temperature of 185℃ (365F) for ten minutes. The preceding subject matter of this paragraph characterizes example 20 of the present disclosure.

The described features, structures, advantages, and/or characteristics of the subject matter of the present disclosure may be combined in any suitable manner in one or more examples and/or implementations. In the following description, numerous specific details are provided to impart a thorough understanding of examples of the subject matter of the present disclosure. One skilled in the relevant art will recognize that the subject matter of the present disclosure may be practiced without one or more of the specific features, details, components, materials, and/or methods of a particular example or implementation. In other instances, additional features and advantages may be recognized in certain examples and/or implementations that may not be present in all examples or implementations. Further, in some instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the subject matter of the present disclosure. The features and advantages of the subject matter of the present disclosure will become more fully apparent from the following description and appended claims, or may be learned by the practice of the subject matter as set forth hereinafter.

WHAT IS CLAIMED IS:

1. A method of repairing surface damage in an exterior surface of a hollow bladder, made of a cured elastomer, the method comprising:

placing first strips, made of an uncured elastomer, at least partially within the surface damage in the exterior surface of the hollow bladder in a side-by-side arrangement such that a slit defined between the first strips is positioned over the surface damage;

sealing the surface damage, the first strips, and a portion of the exterior surface surrounding the surface damage in a vacuum bag;

reducing pressure within the vacuum bag relative to outside the vacuum bag; and

while the pressure within the vacuum bag is reduced, heating the first strips from within the vacuum bag to cure the first strips.

2. The method according to claim 1, further comprising:

applying a peel ply onto the exterior surface of the hollow bladder away from the surface damage in the exterior surface;

placing a caul plate assembly, comprising a caul plate and a breathable release film, onto the exterior surface, over an entirety of the surface damage in the exterior surface, and onto the peel ply such that the breathable release film is interposed between the surface damage and the caul plate and the breathable release film is interposed between the peel ply and the caul plate;

placing a heating blanket onto the caul plate assembly; and

sealing the peel ply, the caul plate assembly, and the heating blanket, together with the surface damage, the first strips, and the portion of the exterior surface surrounding the surface damage, in the vacuum bag;

wherein the first strips are heated from within the vacuum bag by the heating blanket.

3. The method according to claim 2, further comprising:

placing a woven polyester ply onto the heating blanket such that the woven polyester ply is interposed between the heating blanket and the vacuum bag; and

sealing the woven polyester ply within the vacuum bag.

4. The method according to claim 2 or 3, further comprising applying a secondary peel ply onto the heating blanket such that the heating blanket is interposed between the secondary peel ply and the caul plate assembly.

5. The method according to any one of claims 1-4, wherein sealing the surface damage, the first strips, and a portion of the exterior surface surrounding the surface damage in the vacuum bag comprises:

applying a pressure-sensitive sealant tape onto the exterior surface of the hollow bladder; and

adhering the vacuum bag to the pressure-sensitive sealant tape.

6. The method according to any one of claims 1-5, wherein:

the surface damage is a through-hole, extending from the exterior surface to an interior surface of the hollow bladder; and

the method further comprises placing second strips, made of the uncured elastomer, within the through-hole in a stacked arrangement such that the second strips are interposed between the first strips and an interior cavity of the hollow bladder.

7. The method according to claim 6, further comprising placing a third strip, made of a fiber-reinforced polymer, within the through-hole between the second strips.

8. The method according to claim 6, further comprising placing third strips, made of a fiber-reinforced polymer, within the through-hole between the second strips such that each one of the third strips is sandwiched between a respective two of the second strips.

9. The method according to any one of claims 6-8, further comprising forming a bevel around an entire perimeter of the through-hole, wherein the first strips are further placed at least partially within a space defined by the bevel.

10. The method according to any one of claims 6-9, further comprising sealing the through-hole along an interior surface of the hollow bladder with a pressure-sensitive sealant tape adhered to the interior surface of the hollow bladder.

11. The method according to any one of claims 1 to 10, wherein:

the surface damage has a depth extending into a thickness of the hollow bladder;

the surface damage has a width;

each of the first strips has a width; and

the width of each one of the first strips is less than the width of the surface damage.

12. The method according to claim 10, further comprising placing a release film within the through-hole between the second strips and the pressure-sensitive sealant tape.

13. A method of repairing a through-hole in a hollow bladder, made of a cured elastomer, the through-hole extending from an exterior surface of the hollow bladder to an interior surface of the hollow bladder and the method comprising:

placing strips, made of an uncured elastomer, within the through-hole of the hollow bladder such that a slit defined between the strips is positioned over the through-hole;

sealing the through-hole along the interior surface of the hollow bladder with a pressure-sensitive sealant tape adhered to the interior surface of the hollow bladder;

reducing a pressure at the exterior surface around the through-hole, to below atmospheric pressure, after the through-hole is sealed along the interior surface with the pressure-sensitive sealant tape;

curing the strips by heating the strips while the through-hole is sealed along the interior surface by the pressure-sensitive sealant tape and while the pressure at the exterior surface around the through-hole is reduced; and

removing the pressure-sensitive sealant tape from the interior surface of the hollow bladder after the strips are cured.

14. The method according to claim 13, further comprising inserting the pressure-sensitive sealant tape, from a location exterior to the hollow bladder, through the through-hole and into an interior cavity of the hollow bladder before sealing the through-hole along the interior surface of the hollow bladder with the pressure-sensitive sealant tape, wherein removing the pressure-sensitive sealant tape from the interior surface of the hollow bladder comprises passing the pressure-sensitive sealant tape along the interior cavity of the hollow bladder and out of the hollow bladder at a location away from the through-hole.

15. The method according to claim 14, further comprising:

passing a retrieval line and a hook, fixed to a leading end of the retrieval line, along the interior cavity of the hollow bladder in a first direction toward the through-hole;

after passing the retrieval line and the hook along the interior cavity in the first direction, inserting the hook, from a location within the interior cavity, through the through-hole to a location exterior to the hollow bladder;

attaching the pressure-sensitive sealant tape to the hook after inserting the hook through the through-hole to the location exterior to the hollow bladder; and

after attaching the pressure-sensitive sealant tape to the hook, inserting the hook, from the location exterior to the hollow bladder, through the through-hole and into the interior cavity of the hollow bladder in substantially the first direction to insert the pressure-sensitive sealant tape, from the location exterior to the hollow bladder, through the through-hole and into the interior cavity in substantially the first direction.

16. The method according to claim 15, wherein removing the pressure-sensitive sealant tape from the interior surface of the hollow bladder comprises pulling the retrieval line in a second direction, substantially opposite the first direction, through the interior cavity of the hollow bladder to pull the pressure-sensitive sealant tape away from the interior surface and through the interior cavity of the hollow bladder in the first direction.

17. The method according to claim 15 or 16, wherein:

the pressure-sensitive sealant tape comprises a first portion, having a first length greater than a length of the through-hole, and a second portion spaced apart from the first portion;

the second portion is attached to the hook; and

the method further comprises wrapping the second portion of the pressure-sensitive sealant tape with anti-stick tape.

18. The method according to any one of claims 14-17, further comprising attaching an installation line to the pressure-sensitive sealant tape before the pressure-sensitive sealant tape is inserted through the through-hole and into the interior cavity of the hollow bladder, wherein sealing the through-hole along the interior surface of the hollow bladder with the pressure-sensitive sealant tape comprises:

inserting a first portion of the installation line through the through-hole and into the interior cavity along with the pressure-sensitive sealant tape;

leaving a second portion of the installation line exteriorly of the hollow bladder after the pressure-sensitive sealant tape is inserted into the interior cavity; and

with the pressure-sensitive sealant tape inserted into the interior cavity, pulling the second portion of the installation line away from the interior cavity to raise the pressure-sensitive sealant tape into adhering contact with the interior surface of the hollow bladder.

19. The method according to claim 18, wherein:

attaching the installation line to the pressure-sensitive sealant tape comprises attaching a first end portion to a first location on the pressure-sensitive sealant tape and attaching a second end portion to a second location on the pressure-sensitive sealant tape;

the first location is spaced apart from the second location by a distance less than a maximum length of the through-hole;

inserting the first portion of the installation line through the through-hole and into the interior cavity comprises inserting a first portion of the first end portion of the installation line and a first portion of the second end portion of the installation line through the through-hole and into the interior cavity;

leaving a second portion of the installation line exteriorly of the hollow bladder after the pressure-sensitive sealant tape is inserted into the interior cavity comprises leaving a second portion of the first end portion of the installation line and a second portion of the second end portion of the installation line exteriorly of the hollow bladder after the pressure-sensitive sealant tape is inserted into the interior cavity; and

pulling the second portion of the installation line away from the interior cavity comprises evenly pulling the second portion of the first end portion and the second portion of the second end portion of the installation line away from the interior cavity.

20. A method of repairing surface damage in an exterior surface of a hollow bladder, made of a cured fluoroelastomer, the method comprising:

placing first strips, made of an uncured fluoroelastomer, at least partially within the surface damage in the exterior surface of the hollow bladder such that a slit defined between the first strips is positioned over the surface damage;

reducing a pressure at the exterior surface, around the surface damage and the first strips, to below atmospheric pressure; and

while the pressure at the exterior surface around the surface damage and the first strips is reduced, curing the first strips, by, in order:

heating the first strips at a first temperature of 79.4 ℃ (175F) for fifteen minutes;

heating the first strips at a second temperature of 85℃ (185F) for ten minutes;

heating the first strips at a third temperature of 90.6℃ (195F) for ten minutes;

heating the first strips at a fourth temperature of 137.8℃ (280F) for ten minutes; and

heating the first strips at a fifth temperature of 185℃ (365F) for ten minutes.