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### Method of repairing a pipe

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#### Abstract

A method of repairing a pipe includes providing a pipe repair device, the pipe repair device comprising a spring and a gasket, the gasket defining a gasket top end, a gasket bottom end, and a gasket outer surface, wherein the gasket outer surface defines a plurality of raised ridges and recessed dimples; biasing the pipe repair device to an expanded configuration with the spring inside of the pipe; engaging the raised ridges of the gasket outer surface with an inner wall of the pipe; and creating a suction force between each of the recessed dimples and the inner wall of the pipe to retain the pipe repair device against the inner wall.

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## **Background/Summary**

CROSS-REFERENCE TO RELATED APPLICATIONS (1) The present application is a division of U.S. application Ser. No. 16/987,106, filed Aug. 6, 2020, which claims the benefit of U.S. Provisional Application No. 62/885,021, filed Aug. 9, 2019, each of which is hereby specifically incorporated by reference herein in its entirety.

### **TECHNICAL FIELD**

(1) This disclosure relates to the field of pipe repair. More specifically, this disclosure relates to a pipe repair device comprising a stent for repairing a pipe.

### **BACKGROUND**

(2) Piping systems, including municipal water systems, can develop breaks in pipe walls that can cause leaking. Example of breaks in a pipe wall can include radial cracks, axial cracks, point cracks, etc. Repairing a break in a pipe wall often requires the piping system to be shut off, which can be inconvenient for customers and costly for providers. Further, repairs can necessitate grandiose construction, including the digging up of streets, sidewalks, and the like, which can be costly and time-consuming.

### **SUMMARY**

(3) It is to be understood that this summary is not an extensive overview of the disclosure. This summary is exemplary and not restrictive, and it is intended neither to identify key or critical elements of the disclosure nor delineate the scope thereof. The sole purpose of this summary is to explain and exemplify certain concepts of the disclosure as an introduction to the following complete and extensive detailed description.

(4) Disclosed is a pipe repair device comprising a gasket defining a substantially cylindrical shape, the gasket defining a gasket top end and a gasket bottom end opposite the gasket top end, a gasket outer surface, and a gasket inner surface opposite the gasket outer surface, a top annular seal oriented at the gasket top end and a bottom annular seal oriented at the gasket bottom end, wherein each of the top and bottom annular seals extend substantially radially outward from the gasket outer surface; and a spring engaging the gasket inner surface and biasing the pipe repair device to an expanded configuration, wherein the gasket, top annular seal, and bottom annular seal are configured to engage an inner wall of a pipe in the expanded configuration.

(5) Also disclosed is a pipe repair device comprising a gasket defining a substantially cylindrical shape, the gasket defining a gasket top end and a gasket bottom end opposite the gasket top end, a gasket outer surface, and a gasket inner surface opposite the gasket outer surface, the gasket outer surface defining a plurality of raised ridges, the raised ridges extending about a circumference of the gasket outer surface; and a spring engaging the gasket inner surface, wherein the pipe repair device is configurable in an expanded configuration and one of a compressed configuration and folded configuration, and wherein the spring biases the pipe repair device to the expanded configuration.

(6) Further, a method of repairing a pipe is disclosed, the method comprising providing a pipe



repair device, the pipe repair device comprising a spring and a gasket, the gasket defining a gasket top end, a gasket bottom end, and a gasket outer surface, wherein the gasket outer surface defines a plurality of raised ridges and recessed dimples; biasing the pipe repair device to an expanded configuration with the spring inside of the pipe; engaging the raised ridges of the gasket outer surface with an inner wall of the pipe; and creating a suction force between each of the recessed dimples and the inner wall of the pipe to retain the pipe repair device against the inner wall.

(7) Disclosed is a stent spring for a pipe repair device comprising one or more strands defining a tubular structure, the tubular structure defining a spring top end and a spring bottom end; a top band extending around a banded portion of the tubular structure at the spring top end; and a bottom band extending around the banded portion of the tubular structure at the spring bottom end.

(8) Various implementations described in the present disclosure may include additional systems, methods, features, and advantages, which may not necessarily be expressly disclosed herein but will be apparent to one of ordinary skill in the art upon examination of the following detailed description and accompanying drawings. It is intended that all such systems, methods, features, and advantages be included within the present disclosure and protected by the accompanying claims.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

(1) The features and components of the following figures are illustrated to emphasize the general principles of the present disclosure. Corresponding features and components throughout the figures may be designated by matching reference characters for the sake of consistency and clarity.

(2) FIG. 1 is a top perspective view of a stent spring, in accordance with one aspect of the present disclosure.

(3) FIG. 2 is a top perspective of the stent spring according to another aspect of the present disclosure.

(4) FIG. 3 is a top perspective of the stent spring according to another aspect of the present disclosure.

(5) FIG. 4 is a top perspective of the stent spring according to another aspect of the present disclosure.

(6) FIG. 5 is a top perspective of the stent spring according to another aspect of the present disclosure.

(7) FIG. 6 is a top perspective of the stent spring according to another aspect of the present disclosure.

(8) FIG. 7 is a top perspective of the stent spring according to another aspect of the present disclosure.

(9) FIG. 8A is a top perspective of the stent spring in an expanded configuration according to another aspect of the present disclosure.

(10) FIG. 8B is a top view of the stent spring of FIG. 8A in a folded configuration.

(11) FIG. 9A is a front view of the stent spring in an unrolled configuration according to another aspect of the present disclosure.

(12) FIG. 9B is a top perspective view of the stent spring of FIG. 9A in a rolled configuration.

(13) FIG. 10 is a top perspective of the stent spring according to another aspect of the present disclosure.

(14) FIG. 11 is a top perspective of the stent spring according to another aspect of the present disclosure.

(15) FIG. 12 is a top perspective of the stent spring according to another aspect of the present disclosure.

(16) FIG. 13 is a perspective view of a stent comprising a gasket and the stent spring, in accordance

with one aspect of the present disclosure.

(17) FIG. 14 is a detail cross-sectional view of the stent of FIG. 13 taken along line 14-14 in FIG. 13.

(18) FIG. 15 is a cross-sectional view of the stent according to another aspect of the present disclosure.

(19) FIG. 16 is the gasket according to another aspect of the present disclosure.

(20) FIG. 17A is the gasket according to another aspect of the present disclosure.

(21) FIG. 17B is a detail view of the gasket of FIG. 17A.

(22) FIG. 18 is a perspective view of the stent according to another aspect of the present disclosure.

(23) FIG. 19 is a perspective view of the stent spring according to another aspect of the present disclosure.

(24) FIG. 20 is a perspective view of the stent spring according to another aspect of the present disclosure.

(25) FIG. 21 is a perspective view of the stent spring according to another aspect of the present disclosure.

#### DETAILED DESCRIPTION

(26) The present disclosure can be understood more readily by reference to the following detailed description, examples, drawings, and claims, and the previous and following description. However, before the present devices, systems, and/or methods are disclosed and described, it is to be understood that this disclosure is not limited to the specific devices, systems, and/or methods disclosed unless otherwise specified, and, as such, can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting.

(27) The following description is provided as an enabling teaching of the present devices, systems, and/or methods in its best, currently known aspect. To this end, those skilled in the relevant art will recognize and appreciate that many changes can be made to the various aspects of the present devices, systems, and/or methods described herein, while still obtaining the beneficial results of the present disclosure. It will also be apparent that some of the desired benefits of the present disclosure can be obtained by selecting some of the features of the present disclosure without utilizing other features. Accordingly, those who work in the art will recognize that many modifications and adaptations to the present disclosure are possible and can even be desirable in certain circumstances and are a part of the present disclosure. Thus, the following description is provided as illustrative of the principles of the present disclosure and not in limitation thereof.

(28) As used throughout, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “an element” can include two or more such elements unless the context indicates otherwise.

(29) Ranges can be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

(30) For purposes of the current disclosure, a material property or dimension measuring about X or substantially X on a particular measurement scale measures within a range between X plus an industry-standard upper tolerance for the specified measurement and X minus an industry-standard lower tolerance for the specified measurement. Because tolerances can vary between different materials, processes and between different models, the tolerance for a particular measurement of a particular component can fall within a range of tolerances.

(31) As used herein, the terms “optional” or “optionally” mean that the subsequently described event or circumstance can or cannot occur, and that the description includes instances where said

event or circumstance occurs and instances where it does not.

(32) The word “or” as used herein means any one member of a particular list and also includes any combination of members of that list. Further, one should note that conditional language, such as, among others, “can,” “could,” “might,” or “may,” unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain aspects include, while other aspects do not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more particular aspects or that one or more particular aspects necessarily include logic for deciding, with or without user input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular aspect.

(33) Disclosed are components that can be used to perform the disclosed methods and systems. These and other components are disclosed herein, and it is understood that when combinations, subsets, interactions, groups, etc. of these components are disclosed that while specific reference of each various individual and collective combinations and permutation of these may not be explicitly disclosed, each is specifically contemplated and described herein, for all methods and systems. This applies to all aspects of this application including, but not limited to, steps in disclosed methods. Thus, if there are a variety of additional steps that can be performed it is understood that each of these additional steps can be performed with any specific aspect or combination of aspects of the disclosed methods.

(34) Disclosed in the present application is a stent for repairing a pipe, and associated methods, systems, devices, and various apparatus. Example aspects of the stent can be oriented in an expanded configuration and a compressed or folded configuration. Some aspects of the stent can comprise a stent spring and a gasket. It would be understood by one of skill in the art that the disclosed stent is described in but a few exemplary aspects among many. No particular terminology or description should be considered limiting on the disclosure or the scope of any claims issuing therefrom.

(35) FIG. 1 illustrates a first aspect of a stent spring **100**, according to the present disclosure. Example aspects of the stent spring **100** can define a spring force and can be expandable and compressible, such that the stent spring **100** can be oriented in an expanded configuration, as shown in FIG. 1, and a compressed configuration (not shown) or folded configuration (shown in FIG. 8B). In the depicted aspect, the stent spring **100** can comprise a plurality of strands **110** formed into a substantially cylindrical, tubular structure. The strands **110** can define a plurality of openings **112** therebetween. In a particular aspect, as shown, the strands **110** can be generally X-shaped strands **120** arranged in circular pattern. Example aspects of the strands **110** can be substantially resilient and flexible. The flexibility of the strands **110** can allow the stent spring **100** to be compressed in the compressed configuration, and the resiliency of the strands **110** can provide the stent spring **100** with the spring force, which can bias the stent spring **100** from the compressed configuration to the expanded configuration. The cylindrical, tubular structure of the stent spring **100** can define opposing open ends (e.g. a spring top end **102** and a spring bottom end **104** opposite the spring top end **102**). The stent spring **100** can further define an outer surface **106** and an opposite inner surface **108**. The inner surface **108** can define a void **130**, which can extend between the spring top end **102** and spring bottom end **104** and can allow fluid to pass therethrough, for example, when the stent spring **100** is received in a pipeline. According to example aspects, the stent spring **100** can be formed from a metal material, such as stainless steel, spring steel, aluminum, nitinol, cobalt chromium, or any other suitable material. In other aspects, the stent spring **100** can be formed from a plastic material, such as, for example, nylon, POM (polyoxymethylene), or PVC (polyvinyl chloride). In still another aspect, the stent spring **100** can be formed from a carbon fiber material. Optionally, the material can be an NSF certified material that can comply with various public health safety standards. For example, in some aspects, the material can be approved as safe for use in drinking-water applications.

(36) Moreover, in some aspects, the stent spring **100** can comprise a coating, such as, for example, a rubber or liquid metal coating. The coating can improve mechanical properties of the stent spring **100**. For example, the coating can improve the tensile strength of the stent spring **100** by providing a flexible and/or springy outer layer. For example, in one aspect, the stent spring **100** can be coated in a Plasti Dip® coating. A Plasti Dip® coating is a synthetic rubber coating that can be applied by spraying, brushing, dipping, or the like, and which can be configured to air dry. The Plasti Dip® material can be non-slip, flexible, durable, and insulating material in some aspects. In another example aspect, the stent spring **100** can be coated in a Flex Seal® coating. The Flex Seal® coating is a synthetic rubber coating similar to the Plasti Dip® coating and can be applied by pouring, rolling, dipping, spraying, or the like, and can be durable, flexible, insulating, and water resistant. In other aspects, the coating can be any other suitable coating known in the art. As such, example aspects of the coating can be flexible and can improve the flexibility of the stent spring **100**. In some example aspects, the coating can also be a non-slip coating configured to improve the grip of the stent spring **100** with any component(s) engaged by the stent spring **100**, such as, for example, a gasket **1310** (shown in FIG. **13**). In some aspects, the coating can also be corrosion resistant, or a separate coating can be applied for corrosion resistance. For example, a corrosion resistant coating can comprise a zinc-nickel material, phosphate, electrophoretic paint (e-coating), polyester, fusion-bonded epoxy (FBE), or any other suitable corrosion resistant material.

(37) According to example aspects, each of the X-shaped strands **120** can be connected to the adjacent X-shaped strands **120** proximate to an upper end **122** and a lower end **124** thereof. The upper end **122** of each X-shaped strand **120** can generally correspond to the spring top end **102** of the stent spring **100**, and the lower end **124** of each X-shaped strand **120** can generally correspond to the spring bottom end **104** of the stent spring **100**. In the preset aspect, each of the X-shaped strands **120** can be connected to adjacent X-shaped strands **120** by one or more connecting bridges **140**. For example, as shown, a first X-shaped strand **120a** can be connected to an adjacent second X-shaped strand **120b** proximate the upper end **122** thereof by a first connecting bridge **140a** and proximate the lower end **124** thereof by a second connecting bridge **140b**. The first X-shaped strand **120a** can also be connected to an adjacent third X-shaped strand **120c** proximate the upper end **122** thereof by a third connecting bridge **140c** and proximate the lower end **124** thereof by a fourth connecting bridge **140d**.

(38) According to various example aspects, the stent spring **100** can further comprise one or more wires **150** connected to one or more of the strands **110**. For example, in a particular aspect, the wires **150** can be a plurality of Nitinol super-elastic wires **152**, which can be configured to provide added flexibility to the stent spring **100**. In some aspects, a Nitinol super-elastic wire **152** can extend between the upper ends **122** of each adjacent X-shaped strand **120** and between the lower ends **124** of each adjacent X-shaped strands **120**. Note, only a few representative Nitinol super-elastic wires **152** are illustrated in the present aspect. More or fewer wires **150** may be provided in other aspects.

(39) According to example aspects, the gasket **1310** (shown in FIG. **13**) can be configured to wrap around the outer surface **106** of the stent spring **100**, and the gasket **1310** and stent spring **100** together can define a pipe repair device **1300** (shown in FIG. **13**). The pipe repair device **1300** can be expanded within a pipe (not shown) of the pipeline such that the gasket **1310** can engage an inner wall (not shown) of the pipe where a crack or other damage is present, in order to create a watertight seal between the pipe repair device **1300** and the inner wall of the pipe to prevent leaking at the damage site. According to example aspects, the connecting bridges **140** and the wires **150** can provide added support to the gasket **1310** proximate to the spring top end **102** and spring bottom end **104**, such that the gasket **1310** can be pressed firmly against the inner wall of the pipe at the connecting bridges **140**. The added support for the gasket **1310** can aid in retaining the pipe repair device **1300** in place against the inner wall of the pipe by preventing the fluid flowing through the pipe from flowing between the gasket **1310** and the inner wall and pulling the pipe

repair device **1300** downstream.

(40) FIG. 2 illustrates the stent spring **100** according to another example aspect of the present disclosure. The stent spring **100** can be similar to the stent spring **100** of FIG. 1; however, in the present aspect, each of the X-shaped strands **120** can be monolithically formed with adjacent X-shaped strands **120** at the upper and lower end **122,124** thereof to define a substantially tubular mesh structure comprising the plurality of openings **112**. Also, as shown, a one of the connecting bridges **140** can extend across each of the corresponding upper end **122** and lower end **124** of each X-shaped strand **120**. Furthermore, each of the connecting bridges **140** of the present aspect can define a break **242** formed at a central region thereof, such that each connecting bridge **140** can define a first bridge portion **244** and a second bridge portion **246**. The first bridge portion **244** can be configured to press against and slide along the second bridge portion **246** when compressed, creating additional spring force. The added spring force can aid in biasing the stent spring **100** back to the expanded configuration and in pressing the gasket **1310** (shown in FIG. 13) against the inner wall of the pipe at the spring top end **102** and spring bottom end **104**.

(41) As such, in the present aspect, the connecting bridges **140** can allow the stent spring **100** to evenly and circumferentially engage the gasket **1310** at the spring top end **102** and spring bottom end **104** and can provide added support for pressing the gasket **1310** against the inner wall of the pipe at the spring top and bottom ends **102,104**. Furthermore, as illustrated in FIG. 2, in some aspects, a diameter  $D_{sub.1}$  of the stent spring **100** defined at the spring top end **102** and spring bottom end **104** can be greater than a diameter  $D_{sub.2}$  of the stent spring **100** defined at a middle section **206** thereof. The increased diameter  $D_{sub.1}$  at the spring top end **102** and spring bottom end **104** can increase the force with which the stent spring **100** presses the gasket **1310** into the inner wall of the pipe at the spring top and bottom ends **102,104** thereof.

(42) FIG. 3 illustrates another example aspect of the stent spring **100** according to the present disclosure. As shown, the tubular mesh structure of the stent spring **100** can comprise a plurality of the strands **110** arranged to define the openings **112** therebetween. In the present aspect, the stent spring **100** can comprise a top band **310** extending around a banded portion **320** of the circumference of the stent spring **100** at the spring top end **102** thereof, and a bottom band **312** extending around the banded portion **320** of the stent spring **100** at the spring bottom end **104** thereof. The top band **310** and bottom band **312** can be monolithically formed with the adjoining strands **110** in some aspects; however, in other aspects, the top band **310** and/or bottom band **312** can be coupled to the corresponding strands **110** by any suitable fastener, such as an adhesive, a mechanical fastener, or the like. The top band **310** and bottom band **312** can increase the resiliency of the stent spring **100** around the banded portion **320**, and can aid in pressing the gasket **1310** (shown in FIG. 13) into the inner wall of the pipe at the spring top end **102** and spring bottom end **104**, as described above. Furthermore, according to example aspects, an un-banded portion **330** of the circumference of the stent spring **100** around which the top band **310** and bottom band **312** do not extend can be more flexible than the banded portion **320** of the circumference, and can allow for easier compression and/or folding of the stent spring **100** at the un-banded portion **330**.

(43) FIG. 4 illustrates the stent spring **100** according to another example aspect that can be similar to the stent spring **100** of FIG. 3, wherein the stent spring **100** can comprise the top band **310** and the bottom band **312** extending around the banded portion **320**. The un-banded portion **330** can comprise increased flexibility over the banded portion **320**, which can allow for easy folding and/or compression of the stent spring **100** at the un-banded portion **330**. In the present aspect, the strands **110** of the stent spring **100** can be configured differently than the strands **110** of the stent spring **100** of FIG. 3, such that the openings **112** formed by the stands can define different shapes. The top and bottom bands **310,312** of the present aspect can also be notably thinner than the top and bottom bands **310,312** of FIG. 3.

(44) FIG. 5 illustrates an example aspect of the stent spring **100** that can be similar to the stent springs **100** of FIGS. 3 and 4. The stent spring **100** can comprise the top band **310** and bottom band

**312** extending around the banded portion **320**. However, in the current aspect, the stent spring **100** can further comprise a second top band **510** and a second bottom band **512** extending around a second banded portion **520** of the stent spring **100**. As shown, un-banded portions **330** can be formed between the banded portion **320** and second banded portion **520**. The un-banded portions **330** can comprise increased flexibility as opposed to the banded portion **320** and second banded portion **520**, which can allow for easy folding and/or compression of the stent spring **100**. FIG. 6 illustrates the stent spring **100** according to another example aspect that can be substantially similar to the stent spring **100** of FIG. 5.

(45) FIG. 7 illustrates another example aspect of the stent spring **100**, according to the present disclosure. As shown, in some aspects, the stent spring **100** may not comprise the connecting bridges **140**, the wires **150**, or the top and bottom bands **310,312**. However, upper portions **710** and lower portions **712** of the strands **110** formed at the spring top end **102** and spring bottom end **104**, respectively, can provide added support to the gasket **1310** (shown in FIG. 13) at the spring top end **102** and spring bottom end **104** to aid in retaining the pipe repair device **1300** (shown in FIG. 13) in position within the pipe.

(46) FIG. 8A illustrates another example aspect of the stent spring **100** in accordance with the present disclosure. As shown, the stent spring **100** can define the tubular mesh structure comprising a plurality of the strands **110**, and the strands **110** can define the plurality of openings **112**. In the present aspect, the stent spring **100** can be monolithically formed as a singular component. For example, the stent spring **100** can be laser cut from a sheet of material, such as, for example, a sheet of stainless steel. In other aspects, the stent spring **100** can be formed by stereolithography (e.g., 3D printing), or by any other suitable manufacturing method suitable for forming the mesh structure of the stent spring **100**. Moreover, in the present aspect, the stent spring **100** can be configured to be folded instead of compressed, as shown in FIG. 8B. Furthermore, as shown, a plurality of holes **810** can be formed around the circumference of the stent spring **100** at the middle section **206** thereof. According to example aspects, each of the holes **810** can be configured to receive an eye bolt (not shown) therethrough, and the eye bolt can define a loop. In other aspects, any other suitable device providing a loop can be provided. A wire, or in other aspects, a cord, thread, or the like, can be passed through the loops of the eye bolts, and a pulling force can be applied to the wire to draw the stent into the folded configuration. In other aspects, the wire (or cord, thread, or the like) can be fed directly through the holes **810**, and the pulling force can be applied to the wire to draw the stent into the folded configuration. FIG. 8B illustrates a top view of the stent spring **100** in the folded configuration, in accordance with one particular aspect.

(47) FIGS. 9A and 9B illustrates an example aspect of the stent spring **100** that can be substantially similar to the stent spring **100** of FIGS. 8A and 8B. In the present aspect, the stent spring **100** can be manufactured in an unrolled configuration, as shown in FIG. 9A, and can then be reconfigured into a rolled configuration, as shown in FIG. 9B, to define the substantially tubular mesh structure. Referring to FIG. 9A, the stent spring **100** can define a first side **910** and an opposite second side **912**. In the present aspect, a first tab **920** and a second tab **930** can be formed at each of the first side **910** and second side **912**. To retain the stent spring **100** in the rolled configuration, as shown in FIG. 9B, the first tabs **920** can be fastened to one another, such as, for example, by spot welding, and the second tabs **930** fastened to one another, such as, for example, by spot welding. In other aspects, the first side **910** of the stent spring **100** can be attached to the second side **912** by an alternative fastener, such as, for example, one or more nut and bolt assemblies, adhesives, clips, snaps, ties, or any other suitable fastener or combination of fasteners known in the art. Furthermore, according to example aspects, the rolled stent spring **100** can be heat treated to harden the stent spring **100**. For example, in one particular example aspect, the stent spring **100** can be hardened to between about 40-45 HRC.

(48) FIG. 10 illustrates another example aspect of the stent spring **100** that can be similar to the stent spring **100** of FIGS. 8A and 8B; however, the stent spring **100** of the present aspect can

comprise a greater amount of strands **110** than the prior aspect, and thus can define more of the openings **112**, as shown. The stent spring **100** of the present aspect can be substantially the same in size as compared to the prior aspect, and as such, each of the openings **112** can define a smaller width  $W_{sub.1}$  than the openings **112** of the prior aspect. In some aspects, providing a stent spring **100** comprising more strands defining smaller openings **112** can increase the flexibility of the stent spring **100** and allow for easier folding and/or compression. FIG. **11** illustrates still another example aspect of the stent spring **100**, wherein the size and shape of the strands **110** and openings **112** can be similar to the stent spring **100** of FIGS. **8A** and **8B**; however, the present aspect can further comprise the top band **310** and the bottom band **312** extending around the banded portion **320** of the stent spring **100**.

(49) FIG. **12** illustrates an example aspect of the stent spring **100**, according to the present disclosure, wherein the stent spring **100** can be adjustable in diameter. In the present aspect, the stent spring **100** can comprise the top band **310** extending fully about the circumference of the stent spring **100** at the spring top end **102** thereof and the bottom band **312** extending fully about the circumference at the spring bottom end **104** thereof. As shown, the stent spring **100** can define the first side **910** and the opposite second side **912**. A plurality of notches **1210** can be formed along a length of the top band **310** and the bottom band **312** adjacent to the first side **910** of the stent spring **100**. Each of the notches **1210** formed in the top band **310** can be configured to substantially align with a corresponding one of the notches **1210** formed in the bottom band **312**. Furthermore, a top locking mechanism **1220** can be positioned at the spring top end **102** proximate to the second side **912** of the stent spring **100**, and a bottom locking mechanism **1230** can be positioned at the spring bottom end **104** proximate to the second side **912**. The top band **310** at the first side **910** of the stent spring **100** can be fed into the top locking mechanism **1220** and the top locking mechanism **1220** can selectively engage one of the notches **1210** in the top band **310** to define a desired diameter of the stent spring **100**. Simultaneously, the bottom band **312** at the first side **910** of the stent spring **100** can be fed into the bottom locking mechanism **1230**, and the bottom locking mechanism **1230** can engage the corresponding notch **1210** on the bottom band **312**. To reduce the diameter of the stent spring **100**, the top and bottom bands **310,312** can be fed further into the corresponding top and bottom locking mechanisms **1220,1230**, respectively, and can be locked in place at the desired reduced diameter. To increase the diameter of the stent spring **100**, the top and bottom bands **310,312** can be drawn further out of the corresponding top and bottom locking mechanisms **1220,1230**, respectively, and locked in place at the desired increased diameter.

(50) FIG. **13** illustrates the pipe repair device **1300** according to an example aspect of the present disclosure. The pipe repair device **1300** can be, for example, a stent **1305**, as shown. According to the present aspect, the stent **1305** can comprise the stent spring **100** and the gasket **1310**, and can generally define a stent diameter  $D_{sub.3}$  and a stent length  $L$ . A center axis **1330** of the stent **1305** can be defined through a center of the void **130**. Example aspects of the gasket **1310** can be formed as a continuous, tubular sleeve structure, as shown, and can be substantially cylindrical in shape. The gasket **1310** can define an outer surface **1312** and an inner surface **1314**. Example aspects of the gasket **1310** can comprise a flexible and compressible material, such as, for example, neoprene. In other aspects, the gasket **1310** can be formed from another synthetic rubber material such as EPDM rubber, natural rubber, foam, epoxy, silicone, a resin-soaked cloth, or any other suitable flexible material. In another aspect, the gasket **1310** can be formed as an uncured resin-filled sleeve, which can be cured in place with UV (ultraviolet) radiation or any other suitable type of radiation. According to example aspects, the gasket **1310** can wrap around the circumference of the stent spring **100**, and the inner surface **1314** of the gasket **1310** can engage the outer surface **106** (shown in FIG. **1**) of the stent spring **100**. In the present aspect, the gasket **1310** can cover the entire outer surface **106** of the stent spring **100**, as shown. However, in other aspects, the gasket **1310** may cover only a portion of the outer surface **106** of the stent spring **100**. In still other aspects, the gasket **1310** may not wrap entirely around the circumference of the stent spring **100**. In

the present aspect, the gasket **1310** can fit snugly on the stent spring **100** by friction fit when the stent spring **100** is in the expanded configuration and can be secured thereto by a fastener (not shown), such as, for example, an adhesive, tie, stitching, or any other suitable fastener known in the art. Furthermore, in some example aspects, a plurality of the stents **1305** can be joined together in series in the axial direction, relative to the center axis **1330** to form a stent **1305** defining a longer stent length L for repairing larger cracks or damage in the pipeline.

(51) Furthermore, as described above, the stent spring **100** can be expandable and compressible. As such, according to example aspects, the stent **1305** can be oriented in an expanded configuration, as shown in FIG. **13**, and a compressed configuration (not shown). In example aspects, the stent spring **100** can bias the stent **1305** radially outward, relative to the center axis **1330**, to the expanded configuration. According to example aspects, the stent **1305** can be expanded within the pipe (not shown) such that the gasket **1310** can engage the inner wall (not shown) of the pipe where a crack or other damage is present, in order to create a watertight seal between the stent **1305** and the inner wall of the pipe to prevent leaking at the damage site.

(52) In the compressed configuration, a compression force (i.e., a pushing force) can be applied to the stent **1305**, for example, by a compression mechanism (not shown). The compression force can overcome the spring force of the stent spring **100**, and the gasket **1310** and stent spring **100** can be compressed or folded radially inward, relative to the center axis **1330**, to define a smaller stent diameter  $D_{sub.3}$  and a smaller overall stent volume than in the expanded configuration. The reduced stent diameter  $D_{sub.3}$  and stent volume in the compressed configuration can allow for easier insertion of the stent **1305** into the pipe or pipeline and easier navigation of the stent **1305** through the pipe or pipeline. When the compression force is removed or reduced to less than the spring force, the stent spring **100** can bias the stent **1305** back to the expanded configuration. In other aspects, any other suitable force, such as a tension force (i.e., a pulling force), can be applied to the stent **1305** to bias the stent **1305** to the compressed configuration or folded configuration.

(53) As shown, the gasket **1310** can define a gasket top end **1316** that can generally correspond to the spring top end **102** and a gasket bottom end **1318** that can generally correspond to the spring bottom end **104**. In the present aspect, a top annular seal **1320** can be positioned at the gasket top end **1316** and a bottom annular seal **1322** can be positioned at the gasket bottom end **1318**. In the present aspect, the top and bottom annular seals **1320,1322** can be formed separately from the gasket **1310** and attached thereto; however, in other aspects, the top and bottom annular seals **1320,1322** may be formed monolithically with the gasket **1310**. According to example aspects, the top annular seal **1320** and bottom annular seal **1322** can provide for an improved seal between the stent **1305** and the pipe at the gasket top and bottom ends **1316,1318** (gasket bottom end **1318** shown in FIG. **13**).

(54) FIG. **14** illustrates a detailed cross-sectional view of top annular seal **1320** at the gasket top end **1316**, which can also be representative of the bottom annular seal **1322**, according to an example aspect. As shown, the top annular seal **1320** can define an annular channel **1422** for receiving the gasket top end **1316** to aid in retaining the top annular seal **1320** on the gasket **1310**. In some aspects, a fastener, such as an adhesive, a mechanical fastener, or any other suitable fastener, may be provided for securing the top annular seal **1320** to the gasket **1310**. In example aspects, the top annular seal **1320** can comprise a first annular sealing flange **1424** extending outwardly therefrom, relative to the center axis **1330** (shown in FIG. **13**), and configured to engage and seal with the inner wall of the pipe. In the present aspect, the first annular sealing flange **1424** can be an elongated sealing fin, as shown. Other aspects of the first annular sealing flange **1424** can define any other suitable shape and size. The top annular seal **1320** can further comprise second annular sealing flange **1426** extending outwardly therefrom, relative to the center axis **1330**, and configured to engage and seal with the inner wall of the pipe. In the present aspect, the second annular sealing flange **1426** can define a substantially cylindrical annular first rib **1428a** coupled to the first annular sealing flange **1424** and a substantially cylindrical annular second rib **1428b**



coupled to the first rib **1428a**, distal to the first annular sealing flange **1424**. In the present aspect, the second annular sealing flange **1426** can at least partially define the annular channel **1422** and can engage the gasket top end **1316** received therein. The bottom annular seal **1322** (shown in FIG. **13**) can be similarly formed. Because the top and bottom annular seals **1320,1322** can extend radially outward relative to the gasket outer surface **1312** of the gasket **1310**, each of the top and bottom annular seals **1320,1322** can define a diameter that can be greater than a diameter of the gasket **1310**. Additionally, as shown, the spring top end **102** and bottom spring end **104** (shown in FIG. **1**) of the stent spring **100** can engage the top annular seal **1320** and bottom annular seal **1322**, respectively, to aid in biasing the top and bottom annular seals **1320,1322** against the inner wall of the pipe.

(55) FIG. **15** illustrates an example aspect of the gasket **1310** comprising the top annular seal **1320** and the bottom annular seal **1322**, according to another aspect of the present disclosure. In the present aspect, the top annular seal **1320** can be a top annular lip **1520** extending substantially radially outward from the gasket **1310**, relative to the center axis **1330** (shown in FIG. **13**), at the gasket top end **1316**, and the bottom annular seal **1322** can be a bottom annular lip **1522** extending substantially radially outward from the gasket **1310**, relative to the center axis **1330**, at the gasket bottom end **1318**. The top and bottom annular ridges **1520,1522** can be monolithically formed with the gasket **1310** in the present aspect (i.e., formed as a single component), and each can define a substantially circular cross-sectional shape, as shown. In other aspects, the top and bottom annular ridges **1520,1522** may not be monolithically formed with the gasket **1310** and/or can comprise any other suitable cross-sectional shape. According to example aspects, the top annular lip **1520** and bottom annular lip **1522** can be configured to engage and seal with the inner wall of the pipe to improve the seal between the stent **1305** and the pipe at the gasket top end **1316** and gasket bottom end **1318**.

(56) Further, as shown, the outer surface **1312** of the gasket **1310** can be a textured outer surface **1312** in some aspects. For example, in the present aspect, the gasket **1310** can define a series of raised ridges **1530** formed on the outer surface **1312** thereof and extending circumferentially around the gasket **1310**, or can otherwise define an uneven, bumpy, or rough outer surface **1312**. In some example aspects, as shown, the raised ridges **1530** can be substantially concentric with the top and bottom annular lips **1520,1522**. Furthermore, in the present aspect, a height of each of the raised ridges **1530** can be less than a height of the top and bottom annular lips **1520,1522**; however, in other aspects, the heights of the raised ridges **1530** and the top and bottom annular lips **1520,1522** can be about equal. According to example aspects, the ridges **1530** of the gasket **1310** can be configured to engage the inner wall of the pipe and can provide an improved grip on the inner wall of the pipe when compared to a smooth outer surface **1312**, particularly when gripping an uneven or rough inner wall of the pipe. In other aspects, the outer surface **1312** of the gasket **1310** can comprise an abrasive material, or can comprise projections, spikes, or grippers, or the like extending therefrom for improving the grip of the gasket **1310** on the inner wall of the pipe. Furthermore, the size, shape, and number of raised ridges **1530** can vary in example aspects.

(57) FIG. **16** illustrates another example aspect of the gasket **1310** wherein the outer surface **1312** can be textured, according to the present disclosure. The gasket **1310** can comprise a plurality of the raised ridges **1530** on the outer surface **1312** thereof, wherein the raised ridges **1530** can be arranged in a crisscross pattern. As such, the ridges **1530** can comprise a plurality of generally vertical ridges **1530a**, relative to the orientation shown, and a plurality of generally horizontal ridges **1530b**, relative to the orientation shown, intersecting the vertical ridges **1530a**. In other aspects, the raised ridges **1530** can be arranged to define any other suitable pattern. A plurality of recessed dimples **1632** can be defined between the vertical and horizontal ridges **1530a,1530b**. The recessed dimples **1632** are substantially square shaped in the present aspect, though in other aspects, the dimples **1632** can define any other suitable shape. According to example aspects, biasing the raised ridges **1530** against the inner wall of the pipe with the stent spring **100** can create

a suction force within the recessed dimples **1632**, which can aid in retaining the pipe repair device **1300** (shown in FIG. **13**) against the inner wall. Furthermore, in the present aspect, each of the ridges **1530** can define a substantially square or rectangular profile having substantially angular edges. However, in other aspects, such as the aspect shown in FIGS. **17A** and **17B**, each of the ridges **1530** can be curved to define a substantially arcuate profile, as shown. In some aspects, ridges **1530** comprising a substantially arcuate profile can provide an improved grip with the inner wall of the pipe, as compared to ridges **1530** defining a substantially square or rectangular profile, as they may more easily conform to variations on the inner wall.

(58) FIG. **18** illustrates another example aspect of the stent **1305** in accordance with the present disclosure. As shown, the stent **1305** can comprise the gasket **1310**. In the present aspect, structural wires **1810**, such as Nitinol structural wires **1812**, can be embedded in, or otherwise attached to, the inner surface **1314** of the gasket **1310** to bias the stent **1305** to the expanded configuration. As such, the Nitinol structural wires **1812** can replace the stent spring **100** (shown in FIG. **1**) in the present aspect. In other aspects, the structural wires **1810** can be formed from any other suitable material that can bias the stent **1305** to the expanded configuration. Furthermore, as shown, the stent **1305** can comprise a wire tightening device **1820** oriented proximate a first side **1822** of the gasket **1310**, which can be opposite a second side **1824** of the gasket **1310**. According to example aspects, a first end **1814** of each wire **1812** oriented proximate the first side **1822** of the gasket **1310** can be fed into a corresponding channel (not shown) in the wire tightening device **1820**, and a second end **1816** of each wire **1812** oriented proximate the second side **1824** of the gasket **1310** can also be fed into the corresponding channel of the wire tightening device **1820**. Once the wires **1812** are in a desired position, wing nuts **1826** provided on the wire tightening device **1820** can be tightened to engage the first and second ends **1814,1816** of each wire **1812** to lock the wires **1812** in place.

(59) FIG. **19** illustrates the stent spring **100** according to another aspect of the present disclosure. The stent spring **100** of the present aspect can comprise a plurality of rods **1910** extending axially, relative to the center axis **1330** (shown in FIG. **13**), about the circumference of the stent spring **100**. In example aspects, a plurality of linear spring arms **1920** can extend between each of the adjacent rods **1910**, with some of the spring arms **1920** angled upward and some of the spring arms **1920** angle downward, relative to the orientation shown, to define a generally chevron pattern around the circumference of the stent spring **100**, as shown. According to example aspects, each of the spring arms **1920** can define a spring force configured to bias the stent spring **100** to the expanded configuration, as shown. Upon application of a suitable compression force, or other force, the spring arms **1920** can be configured to flex relative to the corresponding rods **1910** to which they are connected, allowing the stent spring **100** to be compressed to the compressed configuration. When the compression force is reduced or removed, the spring arms **1920** can bias the stent spring **100** back to the expanded configuration.

(60) FIG. **20** illustrates another example aspect of the stent spring **100** in accordance with the present disclosure. The stent spring **100** of the present aspect can be similar to the stent spring **100** of FIG. **19**. However, as shown, each of the spring arms **1920** extending between adjacent rods **1910** can generally define a V-shape and can be configured to pinch inward at a bottom point **2022** thereof.

(61) FIG. **21** illustrates another example aspect of the stent spring **100**. The stent spring **100** of the present aspect is similar in structure to the stent spring **100** of FIG. **19**; however, the present stent spring **100** is configured to be folded instead of compressed. According to example aspects, as shown, the stent spring can comprise the plurality of axially extending rods **1910** and the linear spring arms **1920** extending therebetween. The first side **910** of the stent spring **100** can be pivotably coupled to the second side **912** of the stent spring **100** by a hinge **2110**. A first cable tube **2112** can be coupled to the hinge **2110**. Moreover, a plate **2120** can be coupled to the stent spring **100** generally opposite the hinge **2110**, and in some aspects, as shown, can extend from the spring top end **102** to the spring bottom end **104**. A second cable tube **2122** can be coupled to the plate

**2120** and can be oriented generally opposite the first cable tube **2112**. In the present aspect, the stent spring **100** can further comprise a cable **2130** defining a first end **2132** and a second end **2134**. The first end **2132** of the cable **2130** can be fed into the second cable tube **2122** through a first opening **2123** thereof, and can exit the second cable tube **2122** through a hole **2124** formed therein. The first end **2132** of the cable **2130** can then be fed through the first cable tube **2112**, and then back into the second cable tube **2122** through the hole **2124**, as shown. The first end **2132** of the cable **2130** can then exit the first opening **2123** of the second cable tube **2122**. In order to fold the stent spring **100**, a pulling force can be applied to the first and second ends **2132,2134** of the cable **2130**. The first and second sides **910,910** of the stent spring **100** can pivot at the hinge **2110** as the first cable tube **2112** is drawn towards the second cable tube **2122** by the pulling force on the cable **2130**. The In other aspects, the cable **2130** can be replaced with a string, cord, or any other suitable flexible strand known in the art.

(62) One should note that conditional language, such as, among others, “can,” “could,” “might,” or “may,” unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more particular embodiments or that one or more particular embodiments necessarily include logic for deciding, with or without user input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular embodiment.

(63) It should be emphasized that the above-described embodiments are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the present disclosure. Any process descriptions or blocks in flow diagrams should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included in which functions may not be included or executed at all, may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present disclosure. Many variations and modifications may be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the present disclosure. Further, the scope of the present disclosure is intended to cover any and all combinations and sub-combinations of all elements, features, and aspects discussed above. All such modifications and variations are intended to be included herein within the scope of the present disclosure, and all possible claims to individual aspects or combinations of elements or steps are intended to be supported by the present disclosure.

## Claims

1. A method of repairing a pipe comprising: providing a pipe repair device, the pipe repair device comprising a spring and a gasket, the gasket defining a gasket top end, a gasket bottom end, and a gasket outer surface, wherein the gasket outer surface defines a plurality of raised ridges and recessed dimples; biasing the pipe repair device to an expanded configuration with the spring inside of the pipe; engaging the raised ridges of the gasket outer surface with an inner wall of the pipe; and creating a suction force between each of the recessed dimples and the inner wall of the pipe to retain the pipe repair device against the inner wall; wherein: the pipe repair device further comprises a top annular seal oriented at the gasket top end and a bottom annular seal oriented at the gasket bottom end; each of the top annular seal and the bottom annular seal extend radially outward from the gasket outer surface; each of the top annular seal and the bottom annular seal defines an annular channel, the gasket top end is received in the annular channel of the top annular seal, and the gasket bottom end is received in the annular channel of the bottom annular seal; and the method

further comprises engaging the top annular seal and the bottom annular seal with the inner wall of the pipe.

2. The method of claim 1, wherein the plurality of raised ridges are arranged in a crisscross pattern.
  3. The method of claim 2, wherein: the plurality of raised ridges defined on the gasket outer surface further defines a plurality of raised horizontal ridges extending about a circumference of the gasket outer surface; the plurality of raised ridges defined on the gasket outer surface further defines a plurality of raised vertical ridges extending from the gasket top end to the gasket bottom end; the raised vertical ridges and the raised horizontal ridges define the recessed dimples therebetween; and engaging the raised ridges of the gasket outer surface with the inner wall of the pipe comprises engaging each of the raised horizontal ridges and the raised vertical ridges with the inner wall of the pipe.
  4. The method of claim 3, wherein each of the recessed dimples is substantially square shaped.
  5. The method of claim 1, wherein each of the plurality of raised ridges defines a substantially rectangular profile and substantially angular edges.
  6. The method of claim 1, wherein at least some of the plurality of raised ridges are concentric with the top annular seal and the bottom annular seal.
  7. The method of claim 1, wherein: each of the top annular seal and the bottom annular seal define a first annular sealing flange and a second annular sealing flange; each second annular sealing flange of the top annular seal and the bottom annular seal defines at least a portion of the annular channel of each of the top annular seal and the bottom annular seal; and engaging the top annular seal and the bottom annular seal with the inner wall of the pipe comprises engaging each of the first annular sealing flange and the second annular sealing flange with the inner wall of the pipe.
  8. The method of claim 7, wherein: the first annular sealing flange defines an elongated sealing fin; and the second annular sealing flange comprises an annular first rib coupled to the elongated sealing fin and an annular second rib coupled to the annular first rib distal to the elongated sealing fin.
  9. The method of claim 1, wherein: the spring defines a spring top end, a spring bottom end opposite the spring top end, and a middle section therebetween; and engaging the top annular seal and the bottom annular seal with the inner wall of the pipe comprises pressing the top annular seal against the inner wall with the spring top end and pressing the bottom annular seal against the inner wall with the spring bottom end.
  10. The method of claim 9, wherein a diameter of the middle section is less than a diameter of the spring top end and a diameter of the spring bottom end.
  11. The method of claim 1, wherein the method further comprises arranging the pipe repair device in a compressed configuration and transporting the pipe repair device through the pipe in the compressed configuration prior to biasing the pipe repair device to the expanded configuration.
  12. The method of claim 11, wherein: the spring comprises a tubular mesh structure comprising a plurality of strands arranged to define a plurality of spring openings therebetween; a void extends axially through the tubular mesh structure; and fluid in the pipe is configured to flow through the void in the expanded configuration.
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