EXPANDABLE SCREEN USING MAGNETIC SHAPE MEMORY ALLOY MATERIAL

BACKGROUND

[0001] The present disclosure relates generally to operations performed and equipment utilized in conjunction with a subterranean well and, in an embodiment described herein, provides an expandable well screen.

[0002] In the course of completing an oil and/or gas well, a string of protective casing can be run into the wellbore followed by production tubing inside the casing. The casing can be perforated across one or more production zones to allow production fluids to enter the casing bore. During production of the formation fluid, formation sand may be swept into the flow path. The formation sand tends to be relatively fine sand that can erode production components in the flow path. In some completions, the wellbore is uncased, and an open face is established across the oil or gas bearing zone. Such open bore hole (uncased) arrangements are typically utilized, for example, in water wells, test wells, and horizontal well completions.

[0003] When formation sand is expected to be encountered, one or more sand screens may be installed in the flow path between the production tubing and the perforated casing (cased) and/or the open wellbore face (uncased). A packer is customarily set above the sand screen to seal off the annulus in the zone where production fluids flow into the production tubing. Various methods of forming a filter may then be performed. In some completions, the annulus around the screen can be packed with a relatively coarse sand (or gravel) which acts as a filter to reduce the amount of fine formation sand reaching the screen. The packing sand is pumped down the work string in a slurry of water and/or gel and fills the annulus between the sand screen and the well casing. In well installations in which the screen is suspended in an uncased open bore, the sand or gravel pack may serve to support the surrounding unconsolidated formation. While sand or gravel packs may serve to filter formation sand, the packing process can be time consuming and in some cases can leave voids. An unconsolidated portion of the wellbore may not be supported at the voids, potentially weakening the completion.

[0004] In some embodiments, the gravel pack may be replaced with an expanding screen assembly that expands out to form a filter. Expandable screens can be used, for example, when the wellbore intersects a productive, yet relatively unconsolidated, zone within a subterranean formation. It would be desirable in many situations to be able to utilize a well screen to filter production from the formation, while foregoing the expense of cementing casing in the wellbore

and performing a gravel packing operation. However, expandable screens can be expensive, require complex installation procedures, and take a significant amount of time to reach an expanded state.

SUMMARY

[0005] In an embodiment, a well screen assembly for use in a wellbore comprises a base pipe comprising one or more fluid passageways, and a shape-memory alloy disposed about the base pipe. The one or more fluid passageways are configured to provide fluid communication between an exterior of the base pipe and a central flowbore, and the shape-memory alloy is configured to transition between an expanded state and a compressed state in response to a trigger.

[0006] In an embodiment, a well screen assembly for use in a wellbore comprises a wellbore tubular string comprising a first screen assembly coupled to a second screen assembly, and a shape-memory alloy disposed about the wellbore tubular string. The shape-memory alloy is configured to provide a selectable resistance to axial flow along an exterior of the wellbore tubular string between the first screen assembly and the second screen assembly.

[0007] In an embodiment, a well screen assembly for use in a wellbore comprises a base pipe comprising one or more fluid passageways, and a shape-memory alloy disposed in a flow path between the exterior of the base pipe and the central flowbore. The one or more fluid passageways are configured to provide fluid communication between an exterior of the base pipe and a central flowbore, and the shape-memory alloy is configured to provide a first resistance to flow in a compressed state and a second resistance to flow in an expanded state.

[0008] In an embodiment, a method comprises providing a trigger to a shape-memory alloy disposed about a base pipe in a wellbore, transitioning the shape-memory alloy from a compressed state to an expanded state in response to the trigger, and establishing fluid communication between an exterior of the base pipe and a central flowbore when the shape-memory allow is in the expanded state. The base pipe comprises one or more fluid passageways configured to provide fluid communication between the exterior of the base pipe and the central flowbore.

[0009] In an embodiment, a method comprises providing a trigger to a shape-memory alloy disposed in a fluid pathway between an exterior of a base pipe and a central flowbore, transitioning the shape-memory alloy from a compressed state to an expanded state in response to the trigger, and changing a fluid resistance through the fluid pathway in response to the transitioning.

[0010] These and other features will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] For a more complete understanding of the present disclosure and the advantages thereof, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description:

[0012] FIGS. 1A-1C are a cut-away view of an embodiment of a wellbore servicing system.

[0013] FIG. 2 is a partial cross-sectional view of an embodiment of a well screen assembly.

[0014] FIG. 3 is a partial cross-sectional view of another embodiment of a well screen assembly.

[0015] FIG. 4 is a partial cross-sectional view of yet another embodiment of a well screen assembly.

[0016] FIG. 5 is a partial cross-sectional view of yet another embodiment of a well screen assembly.

[0017] FIG. 6 is a partial cross-sectional view of yet another embodiment of a well screen assembly.

[0018] FIGS. 7A and 7B are partial cross-sectional views of yet another embodiment of a well screen assembly.

[0019] FIG. 8 is a schematic view of an embodiment of an MSMA actuation mechanism.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0020] In the drawings and description that follow, like parts are typically marked throughout the specification and drawings with the same reference numerals, respectively. The drawing figures are not necessarily to scale. Certain features of the invention may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness. Specific embodiments are described in detail and are shown in the drawings, with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that illustrated and described herein. It is to be fully recognized that the different teachings of the embodiments discussed infra may be employed separately or in any suitable combination to produce desired results.

[0021] Unless otherwise specified, any use of any form of the terms "connect," "engage," "couple," "attach," or any other term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described. In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to …". Reference to up or down will be made for purposes of description with "up," "upper," "upward," or "above" meaning toward the surface of the wellbore and with "down," "lower," "downward," or "below" meaning toward the terminal end of the well, regardless of the wellbore orientation. Reference to inner or outer will be made for purposes of description with "in," "inner," or "inward" meaning towards the central longitudinal axis of the wellbore and/or wellbore tubular, and "out," "outer," or "outward" meaning towards the wellbore wall. As used herein, the term "longitudinal" or "longitudinally" refers to an axis substantially aligned with the central axis of the wellbore tubular, and "radial" or "radially" refer to a direction perpendicular to the longitudinal axis. The various characteristics mentioned above, as well as other features and characteristics described in more detail below, will be readily apparent to those skilled in the art with the aid of this disclosure upon reading the following detailed description of the embodiments, and by referring to the accompanying drawings.

[0022] Various techniques have been used to expand downhole equipment in a wellbore, but there may be potential limitations or issues associated with these techniques. For example, a base pipe may be mechanically expanded by pushing or wedging a cone through its central flow pathway to plastically deform the base pipe to an expanded state. Although the base pipe can be expanded outwardly, its material has to be sufficiently flexible and strong to withstand the mechanical deformation. In addition, connectors between the expandable base pipe sections may be expensive to make. As another example, a swellable material may be coupled to a well screen on an end of a telescoping rod. When the swellable material expands downhole, it may push the well screen into contact with the formation. However, after contacting oil or water, it may take time for the swellable material to reach a fully expanded state. In addition, the swellable material cannot be returned to its original form once expanded, making retrieval difficult. For yet another example, a plastic porous foam may be pre-compressed and retained on a rig surface, and the foam may then be released and allowed to expand downhole. Since this expansion is not

reversible, it may be costly and time consuming to repair or retrieve the porous foam (e.g., in the event of improperly positioning the porous foam).

[0023] To overcome these potential issues, the present disclosure provides a well screen assembly comprising a shape-memory alloy (SMA). SMA is a class of functional materials that may change their shapes and/or dimensions with the application of an external field or trigger. The external field may be thermal, electrical, and/or magnetic. The SMA may be triggered to expand in an activated state and compress or contract in a deactivated state. The SMA may be used with various downhole equipment, such as well screens, filter elements, flow control devices, gravel packs, and the like. The SMA may comprise various types of SMA materials. For example, the SMA may comprise a magnetic shape-memory alloy (MSMA), which may be in the form of a metallic foam. The MSMA may be triggered by at least one magnetic field, which may be provided by an actuator comprising one or more magnets and/or magnetizers. A magnetic strength and/or an orientation of the magnetic field may impact a magnetic field-induced strain (MFIS) of the MSMA. For example, a magnetic field in one orientation (e.g., aligned with a long axis of a crystalline unit lattice) may transition the MSMA to the activated state. Canceling the magnetic field or rotating its orientation (e.g., to be aligned generally perpendicular to the long axis of the crystalline unit lattice) may transition the MSMA to the deactivated state. Additional suitable SMA materials may be actuated based on a temperature change and/or a mechanical stress to transition the SMA material between a compressed and expanded state, or vice versa. In comparison with conventional expandable downhole apparatus, the SMA material disclosed herein may offer several advantages. For example, the disclosed screen assembly comprising the SMA material may be activated and/or deactivated in a short amount of time. Further, the use of an expanding material may allow the base pipe to remain in its original configuration. Still further, the disclosed SMA may be conveniently repaired or retrieved to a rig surface by being deactivated and retrieved.

[0024] The SMA material may be used in a variety of ways. For example, the SMA material may be used to expand one or more filter elements towards a wellbore wall. As another example, the SMA material may be used as a filter element, with or without an additional filter element being present. The SMA material may then be expanded to provide the desired amount of filtering about well screen assembly. During use, the SMA material may be used to trap one or more chemicals and release the chemicals when transitioning from a compressed state to an

expanded state. Further, the resistance to flow through the SMA material may be greater when the SMA material is in the compressed state than the expanded state. This property may be used to vary the resistance to flow in the axial direction along the well screen assembly and/or between well screen assemblies. Further, the SMA material may be placed in a flow path (e.g., a production flowpath through the well screen assembly) and used to vary the resistance to flow through the flowpath. Other suitable uses for the SMA material are also contemplated herein.

[0025] Representatively illustrated in FIGS. 1A-1C is a wellbore servicing system 10 which embodies principles of the present disclosure. Referring initially to FIG. 1A, a well screen assembly 12 including a base pipe 11 and multiple well screens 14, 16, 18 is conveyed into a wellbore 20. The wellbore 20 intersects multiple formations or zones 22, 24, 26 from which it may be desired to produce hydrocarbons such as oil and/or natural gas. The base pipe 11 may comprise one or more fluidic passageways for the hydrocarbons. The well screens 14, 16, 18 may be positioned adjacent respective zones 22, 24, 26. Zonal isolation devices 28, 30, 32, 34 may be interconnected in the well screen assembly 12 between, above, and/or below the well screens 14, 16, 18.

[0026] In the present disclosure, any of the well screens 14, 16, 18 and/or any of the zonal isolation devices 28, 30, 32, 34 may be made of an SMA material that is configured to expand in an activated state and compress or contract in a deactivated state. It should be understood that "expanded" and "compressed" are only relative terms herein, as long as the SMA material occupies a larger volume in the expanded state than in the compressed state. For example, if an SMA material is pre-squeezed on a rig surface, and then released to a natural state in the wellbore, the pre-squeezed state may be referred to as the compressed state, while the natural state may be referred to as the expanded state. On the other hand, if an SMA material is in a natural state on the rig surface, and then enlarged to a larger volume in the wellbore, the natural state may be referred to as the compressed state, while the larger volume state may be referred to as the expanded state.

[0027] The base pipe 11 may be any type of base pipe including, but not limited to, drill pipe, casing, liners, tubular string, jointed tubing, and/or coiled tubing. Further, the base pipe 11 may operate in any orientations (e.g., vertical, deviated, horizontal, and/or curved). In addition, any suitable material may be used for the construction of the base pipe 11. If an MSMA material is used in the well screen assembly 12, in some embodiments, the base pipe 11 or a window of

the base pipe 11 may comprise any suitable non-magnetic (e.g., a non-ferromagnetic) material. In an embodiment, suitable non-magnetic materials may comprise aluminum, aluminum alloy, a plurality of fibers, a polymer, or any combination thereof.

[0028] The wellbore 20 is depicted in FIGS. 1A-1C as being uncased, but it is to be understood that the principles of the present disclosure may also be practiced in cased wellbores. Likewise, although depicted as a vertical wellbore, all or portions of the wellbore 20 may be vertical, deviated at any suitable angle, horizontal, and/or curved. The wellbore 20 may be a new wellbore, an existing wellbore, a straight wellbore, an extended reach wellbore, a sidetracked wellbore, a multi-lateral wellbore, and other types of wellbores for drilling and completing one or more production zones. Further, the wellbore 20 may be used for both producing wells and injection wells. The wellbore 20 may also be used for purposes other than hydrocarbon production such as geothermal recovery and the like.

[0029] The well screen assembly 12 is depicted as including three individual well screens 14, 16, 18, with only one of the well screens being positioned adjacent each of the respective zones 22, 24, 26, but it is to be clearly understood that any number of well screens may be used in the assembly, and any number of the well screens may be positioned adjacent any of the zones, without departing from the principles of the present disclosure. Thus, each of the well screens 14, 16, 18 described herein and depicted in FIGS. 1A-1C may represent multiple well screens.

[0030] In an embodiment, the well screens 14, 16, 18 may be expandable well screens composed of an SMA material. In an embodiment, the zonal isolation devices 28, 30, 32, 34 may be packers, which are set in the wellbore 20 to isolate the zones 22, 24, 26 from each other. The packers may sealingly engage the wellbore 20. As shown in FIG. 1A, the expandable well screens 14, 16, 18 may be in a deactivated state with compressed volumes. As shown in FIG. 1B, the expandable well screens 14, 16, 18 may be transitioned into an activated state, in which they are radially expanded outward. The well screens 14, 16, 18 may expand to any point between the initial outer diameter of the well screens 14, 16, 18 and the wellbore wall. In an embodiment, the screens 14, 16, 18 may contact a wall of wellbore 20 in one or more of the zones 22, 24, 26. Such contact may aid in limiting or preventing the formation materials from collapsing into the wellbore. However, contact between the screens and the wellbore wall is not necessary in keeping with the principles of the present disclosure.

[0031] The expandable well screens 14, 16, 18 may bring about several additional benefits. For example, the radially reduced configuration shown in FIG. 1A may be advantageous during conveyance of the well screens 14, 16, 18 within the wellbore, and the radially expanded configuration shown in FIG. 1B may be advantageous for expanding a filter component, filtering various fluids, and/or modifying the resistance to flow through the well screens 14, 16, 18. In use, the well screens 14, 16, 18 may be expanded into contact with one or more of the zones 22, 24, 26 for radial support of the wellbore, and one or more of the screens 14, 16, 18 may be configured to have sufficient collapse resistance.

[0032] FIG. 2 illustrates a partial cross-sectional view of an embodiment of a well screen assembly 200, which comprises the base pipe 11, an SMA material 202 disposed about the base pipe 11, and a filtering media or element 204 disposed about the SMA 202. The base pipe may comprise any of those types of base pipes described above with respect to FIGS. 1A-1C. The base pipe 11 generally comprises a series of perforations 206 disposed through the wall thereof. While the base pipe 11 is illustrated as being perforated in FIG. 2, the base pipe 11 may be slotted and/or include perforations of any shape so long as the perforations permit fluid communication between an exterior 208 of the base pipe 11 and a central flowbore 210.

[0033] The filter element 204 may screen incoming fluids from the formation. Further, the filter element 204 may serve to limit and/or prevent the entry of sand, formation fines, and/or other particular matter into the SMA 202 and/or the base pipe 11. In an embodiment, the filter element 204 is of the type known as "wire-wrapped," since it is made up of a wire closely wrapped helically about the base pipe 11, with a spacing between the wire wraps being chosen to allow fluid flow through the filter element 204 while keeping particulates that are greater than a selected size from passing between the wire wraps. While a particular type of filter element 204 is used in describing the present disclosure, it should he understood that the generic term "filter element" as used herein is intended to include and cover all types of similar structures which are commonly used in well completions which permit certain flow of fluids through the filter or screen while limiting and/or blocking certain flow of particulates (e.g. other commercially-available screens, slotted or perforated liners or pipes; sintered-metal screens; sintered-sized, mesh screens; screened pipes; prepacked screens and/or liners; or combinations thereof).

[0034] The filter element 204 may comprise one or more layers of filtering material. The size of filtering particles may be determined based on a pore size of each of the one or more

layers. In an embodiment, the filter element 204 may include an outer relatively coarse layer and an inner relatively fine layer. The terms "fine" and "coarse" are used herein to indicate the relative size of particles permitted to pass through the filter layers. That is, the fine layer filters fine or small-sized particles from fluid passing therethrough, while the coarse layer filters coarse or larger-sized particles from fluid passing therethrough. In an alternative embodiment, the filter element 204 may include an outer fine layer and an inner coarse layer.

[0035] As shown in FIG. 2, the SMA material 202 may be disposed between the base pipe 11 and the filter element 204. When transitioned from a compressed state to an expanded state in response to a trigger, the SMA material 202 may expand. Due to the resistance provided by the base pipe 11, the SMA material 202 may expand outwardly and bias the filter element 204 outward. Consequently, a radial distance between the filter element 204 and the wellbore wall 212 may decrease. In an embodiment, the well screen assembly may be configured to allow the filter element 204 to contact the wellbore wall 212. The SMA material 202 may comprise one or more surface features on any face of its surface. For example, the surface of the SMA 202 may comprise corrugations, castellations, scallops, and/or other features, which may be expanded outwardly toward the formation. The features may enhance the distance through which the SMA material expands.

[0036] In an embodiment, the SMA material 202 may also act as a filtering material. The SMA material 202 may comprise a plurality of layers configured to filter a fluid. In an embodiment, the SMA material 202 may include an outer relatively coarse layer and an inner relatively fine layer. In some embodiments, the SMA material 202 may include an outer fine layer and an inner coarse layer. The relative filtering capabilities and capacities of the SMA material 202 may change between the compressed and expanded states, while the relative structure of the coarse and relatively fine layers may remain the same. In an embodiment, a multi-layer filter element 204 may be used along with a multi-layer SMA material 202 to provide a filtering function for the well screen assembly 200.

[0037] In an embodiment, the SMA 202 may take the form of a metallic foam comprising a plurality of pores. The metallic foam may be configured to filter a fluid flowing from the exterior 208 to the central flowbore 210. One or more sizes of the pores may be configured to permit fluid flow while limiting or preventing the flow of particulates above a certain size.

Additionally, due to a relatively higher mechanical strength of metal versus plastic, the strength of the metallic foams may be higher compared to a plastic foam.

[0038] FIG. 3 is a partial cross-sectional view of another embodiment of a well screen assembly 300, which comprises the base pipe 11, the SMA material 202 disposed about the base pipe 11, and the filter element 204 disposed between the base pipe 11 and the SMA material 202. Since various aspects of the well screen assembly 300 may be similar to the well screen assembly 200, the similar aspects will not be further described in the interest of conciseness. As shown in FIG. 3, the SMA material 202 may be placed on an outer surface of the filter element 204. When transitioned from a compressed state to an expanded state in response to a trigger, the SMA material 202 may be configured to expand outwardly toward the wellbore wall 212. Consequently, a space or gap between the SMA material 202 and the wellbore wall 212 may decrease. In an embodiment, the SMA material 202 may contact the wellbore wall 212 to provide support for a formation. In the well screen assembly 300, the SMA material 202 may function in a similar manner as a gravel pack by at least partially filling the space between the filter element 204 and the wellbore/casing wall 212, and in an embodiment, provide a filtering function for fluid flowing from the formation to the central flowbore 210.

[0039] FIG. 4 is another partial cross-sectional view of yet another embodiment of a well screen assembly 400, which comprises the base pipe 11 and the SMA material 202 disposed about the base pipe 11. Since various aspects of the well screen assembly 400 may be similar to the well screen assembly 200 or 300, the similar aspects will not be further described in the interest of conciseness. As shown in FIG. 4, the well screen assembly 400 may not include the filter element (e.g., filter element 204 of FIG. 2 and FIG. 3). Instead, the SMA material 202 may act as the filtering material by itself. In an embodiment, the SMA material 202 may be a metallic foam comprising a plurality of pores. The metallic foam may be configured to filter a fluid flowing from the exterior 208 to the central flowbore 210. One or more sizes of the pores may be configured to permit fluid flow while limiting or preventing the flow of particulate above a certain size. In an embodiment, the SMA material 202 may be configured to provide a selectable resistance to radial flow from the exterior 208 to the central flowbore 210, or vice versa. The SMA may have smaller sizes of pores in the compressed state than the expanded state. Thus, by transitioning from the expanded state to the compressed state, the SMA may provide an increased resistance to radial flow.

[0040] FIG. 5 is a cross-sectional view of yet another embodiment of a well screen assembly 500, which comprises the base pipe 11, a shroud 214 disposed about the base pipe 11, and the SMA material 202 disposed about the shroud 214. Since various aspects of the well screen assembly 500 may be similar to previously described well screen assemblies, the similar aspects will not be further described in the interest of conciseness. In the well screen assembly 500, the SMA material 202 may be disposed on an inner surface of the shroud 214. When transitioned from a compressed state to an expanded state in response to a trigger, the SMA material 202 may be configured to expand inwardly toward the base pipe 11. Consequently, a space or gap between the SMA material 202 and the base pipe 11 may decrease. If desired, the SMA material 202 may contact the base pipe 11 in the expanded state.

[0041] The shroud 214 may be positioned about a portion of the base pipe 11. The shroud 214 comprises a generally cylindrical member formed from a suitable material (e.g. steel) that can be secured to the base pipe 11 via one or more retainer or shunt rings such as retainer rings 216 and 218. The shroud 214 may have a plurality of openings through the wall thereof to provide fluid communication between the annulus 208 and the central flowbore 210. By positioning the shroud 214 over the well screen assembly 500, the base pipe 11, the SMA material 202, and/or any additional filter element can be protected from any accidental impacts during the assembly and installation of the screen assembly in the wellbore that might otherwise severely damage or destroy one or more components of the screen assembly 500.

[0042] FIG. 6 is a cross-sectional view of yet another embodiment of a well screen assembly 600, which comprises the base pipe 11, the shroud 214 disposed about the base pipe 11, and the SMA material 202 disposed about the shroud 214. Since various aspects of the well screen assembly 600 may be similar to previously described well screen assemblies, the similar aspects will not be further described in the interest of conciseness. In the well screen assembly 600, the SMA 202 is disposed on an outer surface of the shroud 214. When transitioned from a compressed state to an expanded state in response to a trigger, the SMA material 202 may be configured to expand outwardly toward the base pipe 11. Consequently, a space or gap between the SMA material 202 and the wellbore wall 212 may decrease. In an embodiment, the SMA material 202 may contact the wellbore wall 212.

[0043] In an embodiment, a well screen assembly 600 for use in a wellbore comprises a base pipe 11 comprising one or more fluid passageways that are configured to provide fluid

communication between an exterior 208 of the base pipe 11 and a central flowbore 210. An SMA material 202 may be disposed in a flow path between the exterior 208 of the base pipe 11 and the central flowbore 210, and the SMA material 202 may be configured to provide a first resistance to flow in a compressed state and a second resistance to flow in an expanded state. FIG. 7A is a partial cross-sectional view of an embodiment of a well screen assembly 650 that comprises the base pipe 11, the filter element 204, a first or inlet port 658, at least one outlet port 206, a housing 656, and a flow restrictor 652 disposed in a fluid path between an exterior 208 of the screen assembly 650 and the central flowbore 210. The SMA material 202 may be disposed in the fluid path within the housing 656.

[0044] In an embodiment, the flow restrictor 652 may be configured to cause a fluid pressure differential across the flow restrictor 652 in response to flowing a fluid through the flow restrictor 652 in at least one direction. In an embodiment, flow restrictor 652 comprises a narrow tube that is disposed in along the base pipe 11. In an embodiment, flow restrictor 652 may be cylindrical in shape and a plurality of cylindrical flow restrictors 652 may be circumferentially positioned about the base pipe 11. In this embodiment, the flow restrictor 652 has at least one fluid passage that extends axially through the flow restrictor 652, having a diameter significantly smaller than the length of the passage. In other embodiments, the flow restrictor 652 may take the form of an orifice restrictor, a nozzle restrictor, a helical restrictor, a u-bend restrictor, combinations thereof, or other types of restrictors suitable for creating a pressure differential across the restrictor. Such flow restrictors may be referred to as ICDs in some contexts. In some embodiments, the flow restrictor may comprise a device configured to create a differential resistance to flow based on the characteristics of the fluid flowing through the flow restrictor. Such devices are commonly referred to as autonomous inflow control devices (AICDs). In some embodiments, the flow restrictor may permit one-way flow, thereby allowing flow in a first direction with minimal resistance and substantially preventing flow in a second direction (e.g., presenting a high resistance). For example, the flow restrictor may comprise a check-valve or other similar device for providing one-way flow.

[0045] In an embodiment, the SMA material 202 may be disposed in series with the flow restrictor 652. FIG. 7A illustrates the SMA material in a compressed state, thereby permitting a flow path between the SMA material 202 and the housing 656. When the SMA material is activated and transitioned to the expanded state (e.g., as shown by the ghosting 654), the SMA

material may expand and contact the inner surface of the housing 656, thereby blocking the flow path between the exterior 208 and the central flowbore 210. The SMA material may allow fluid flow to pass through the SMA material while presenting a higher resistance to flow than through an open flow path when the SMA material is in a compressed state. In some embodiments, the SMA material 202, or additional portions of the SMA material may be disposed within and/or adjacent to the outlet port 206 and/or the inlet port 658.

[0046] FIG. 7B illustrates a partial cross sectional view of an embodiment of a well screen assembly 670 in which the SMA material 202 is disposed within the flow passage of the flow restrictor 652. In this embodiment, the SMA material may be used to provide a selectable resistance to flow through the fluid path between the exterior 208 and the central flowbore 210 and/or the flow restrictor 652 when transitioned between a compressed and expanded state. In this embodiment, the SMA material may present a first resistance to flow in the expanded state and a second resistance to flow in the compressed state. The first resistance to flow may be less than the second resistance to flow due to the greater average pore size and/or fluid pathways through the SMA material when it is expanded. In some embodiments, the average pore size or fluid pathway diameter through the SMA material in the compressed state may be configured to clog with formation fines, thereby substantially preventing fluid flow through the flow restrictor 652. In an embodiment, the ability to clog the SMA material may be used to effectively block off flow through the flow restrictor 652, while expanding the SMA material 202 may re-establish flow through the flow restrictor 652.

[0047] While FIGS. 2-7B demonstrate several embodiments of configuring a well screen assembly in a wellbore, it should be understood that other configurations may be similarly implemented without departing the principles of the present disclosure. For example, the shroud 214 may be incorporated into any of the well screen assembly 200, 300, or 400, in which the shroud may be disposed about the base pipe 11. In this case, the SMA 202 and/or filter element 204 may be disposed inside or outside the shroud 214. For another example, the filter element 204 may be incorporated into the well screen assembly 500 or 600, in which the filter element 204 may be disposed at any desired position. The filter element 204 may be disposed on, for example, an outer surface of the base pipe 11, an inner or outer surface of the SMA 202, and/or an inner or outer surface of the shroud 214. For yet another example, some embodiments of well

screen assemblies (e.g., the well screen assembly 200) may be a pipe-less screen assembly, wherein a wire-wrapped screen may be used in place of the base pipe 11.

[0048] The SMA material may also be used to alter the annular flow profile along the well screen assemblies. Returning to FIGS. 1A-1C, one or more of the zonal isolation devices 28, 30, 32, 34 may comprise expandable sealing devices comprising an SMA material. The expandable sealing devices comprising the SMA material may be configured to provide a selectable resistance to axial flow across zones or screen assemblies through the annulus formed between the exterior of the wellbore tubular string and the wellbore wall. The resistance to flow may comprise any resistance to flow, which may range from allowing an annular flow to substantially preventing annular flow through the one or more sealing devices. The expandable sealing device comprising the SMA material may be used with any of the other embodiments comprising the SMA material described herein.

[0049] The resistance to annular flow may be created in a number of ways. In an embodiment, the SMA material may provide an increased resistance to axial flow by expanding to contact a wall of the wellbore 20 (e.g., as shown in FIG. 1A and FIG. 1B). In some embodiments, the SMA material may provide the expansion force to engage a separate sealing member against the wellbore wall, thereby increasing the resistance to annular flow past the sealing device. In an embodiment, the SMA material may contact the wellbore wall so that annular fluid flow passes through the SMA material. The SMA material may be configured to provide an increased resistance to flow, for example, due to the structure of the SMA material and/or based on being configured to clog over time to provide an increased resistance to annular flow. The one or more sealing devices could then be deactivated (e.g., transitioned to a compressed state as shown in FIG. 1C). In the compressed state, the sealing element comprising the SMA material may provide a decreased resistance to axial flow by compressing to create a flow passage comprising gap or space between the sealing element and the wellbore wall, which may act as a flow channel for annular flow between zones or sections.

[0050] In an embodiment, the resistance to annular flow may be created by transitioning the SMA material to a deactivated/compressed state. For example, the SMA material may comprise a porous material such as a metal foam, which may have a smaller average pore size in the compressed state than in the expanded state. As another example, one or more flow passages (e.g., tubular channels, slots, etc.) may be disposed through the SMA material, and the SMA

material may be configured to open the one or more flow passages in the expanded state while closing the one or more flow passages in the compressed state. Thus, by transitioning to the compressed state, the SMA may provide an increased resistance to flow through the SMA material. In an embodiment, the SMA material may be placed in an annular flow path so that any annular flow may pass through the SMA material. The SMA material may be configured to transition between the expanded and compressed states while remaining within the annular flow path. When expanded, the SMA material may present a first resistance to flow based on the increased pore size and/or the opening of the one or more flow passages through the SMA material. When compressed, the SMA material may present a second resistance, which may be higher than the first resistance, to flow based on the decreased pore size and/or the closing of the one or more flow passages through the SMA material.

[0051] In an embodiment, any of the embodiments of the well screen assemblies comprising an SMA material may be used to provide one or more chemicals about the well screen assembly. An SMA (e.g., the SMA 202 or the MSMA) may be configured to contain one or more chemical components disposed within one or more interior space (e.g., in one of a plurality of interior pores or voids formed within the SMA material). In an embodiment, the chemical components may comprise solid particles, powders, fluid containing spheres, gels, or any other suitable form. The chemical components may be loaded or trapped within the interior space of the SMA material at the surface of the wellbore when the SMA material is in an expanded state. The SMA material may then be transitioned to a compressed state to capture the chemical components within the SMA material. Once positioned within the wellbore the SMA material may be transitioned into an expanded state, so that the trapped chemical components may be released. In an embodiment, the chemical components may comprise any chemicals suitable for use in drilling, completing, stimulating, or otherwise treating a wellbore. Suitable chemicals may comprise one or more organic acids (e.g., formic acid, acetic acid, citric acid, glycolic acid, lactic acid, 3-hydroxypropionic acid, a C1 to C12 carboxylic acid, an aminopolycarboxylic acid such as hydroxyethylethylenediamine triacetic acid, and any derivative thereof, any combination thereof, and/or any salt thereof), inorganic acids (e.g., hydrochloric acid, hydrofluoric acid, hydrobromic acid, sulfuric acid, phosphoric acid, and/or nitric acid), inorganic acid salts, fluid loss control additives, scale inhibitors, corrosion inhibitors, catalysts, clay stabilizers, biocides, bactericides, friction reducers, iron control agents, solubilizers, pH adjusting agents (e.g.,

buffers), gel breakers (e.g., enzyme, oxidizing, acid buffer, and/or delayed gel breakers), and any combination thereof.

[0052] In use, a variety of SMAs may be employed in a wellbore. Depending on the type of constituent material, SMAs may respond to various triggers including a magnetic field, a temperature change, a mechanical stress, or any combination thereof. Various actuators, such as one or more magnetizers, heating/cooling circuits, mechanical energy release mechanisms, injected fluids at different temperature, heat from the formation, or any combination thereof, may be configured to provide the various triggers. For example, a heat-triggered SMA may be deployed in a steam injection well. Heat carried in injected steam may raise the temperature of the SMA, which may cause the SMA to transition from a compressed state to an expanded state. In an embodiment, magnetic shape-memory alloys (MSMAs, sometimes also referred to as ferromagnetic shape-memory alloys) may be triggered between an activated state and a deactivated state, or vice versa, by one or more magnetic fields. Implementation details of MSMAs are described in more detail herein.

[0053] MSMAs are solid crystals made up of a combination of materials that react to magnetic fields by either stretching out or contracting. An MSMA usually comprises a combination of various metals. For example, an MSMA may comprise anti-ferromagnetic materials, such as a mixture of nickel (Ni), cobalt (Co), and manganese (Mn), or a mixture of Mn, iron (Fe), and copper (Cu). For another example, an MSMA may comprise ferromagnetic materials, such as a mixture of Fe and palladium (Pd), a mixture of Fe and platinum (Pt), or a mixture of Ni, Mn, and Ga. Depending on the constituents of the MSMA, its fabrication process and properties may vary. Herein, an MSMA comprising Ni, Mn, and Ga is further described as an example. In practice, a Ni-Mn-Ga MSMA may be fabricated from purified nickel (Ni), manganese (Mn), and gallium (Ga). These metals may be mixed using flexible ratios. For example, Ni may vary between about 50%-55%, Mn between about 20%-28%, and Ga between about 21%-25% (three percentages should add up to 100% in any case).

[0054] The MSMA may be fabricated into a porous metallic foam with open pores. This porous foam may be fabricated via any suitable technique. For example, a replication casting method may be used to manufacture the MSMA foam. In this process, high-temperature tolerant powders (e.g., made of sodium aluminate $NaAlO_2$) may be placed in an alumina crucible. The size of the powders may determine the size of metallic foam. If desired, the powders may be

lightly sintered in air (e.g., at about 1500 °C for about 3 hours) to create neck-like connections between powders, which may ensure that the powders do not substantially move when molten metal is infiltrated. Then, a parent ingot, which is a mixture of Ni, Mn, and Ga, may be placed on top of the sintered powders. The ingot may be heated in a furnace to an appropriate temperature (e.g., target temperature of about 1200 °C with ramp rate of about 7 °C/minute) under a vacuum condition (e.g., about 3.5×10-6 torr pressure). The temperature of the ingot may be maintained for a period of time (e.g., at about 1200 °C for about 24 minutes). Meanwhile, high-purity argon gas may be introduced into the furnace at an appropriate pressure (e.g., at about 1.34 times atmospheric pressure) to push the molten alloy into the sintered powders.

[0055] After infiltration, the metallic foam may be chemically homogenized in a vacuum (e.g., at about 1000°C for about 1 hour). Then, the metallic foam may be subjected to a stepwise heat-treatment (e.g., at about 725 °C for about 2 hours, then at about 700°C for about 10 hours, then at about 500°C for about 20 hours) to solidify. During the heat treatment, a Heusler alloy (or L21) lattice structure may be established, which may be important for the functioning of the MSMA. After solidification into a crystalline form, the metallic foam and the casting mold of sintered powders may be immersed in an acidic solution (e.g., H_2SO_4), so that the casting mold may be leached away. Sonication may be used at room temperature to expedite removal of the casting mold. The whole assembly may also be immersed additionally in a solution with about 10% HCl under sonication to remove any remaining $NaAlO_2$ space holder. After removal of the casting mold or space holder, a framework of thin metal struts resembling a sponge may be left.

[0056] The MSMA foam may comprise a plurality of pores, where the average size is determined by the fabrication process. For example, if relatively large powders (e.g., with spherical diameter around 500 μm) are used to construct the casting mold, the casted MSMA foam may accordingly have relatively large pore size. Otherwise, if relatively small powders (e.g., with spherical diameter around 80 μm) are used to construct the casting mold, the casted MSMA foam may accordingly have relatively small pore size. Porosity may refer to a volume ratio of the pores to a total volume of the MSMA foam. In use, porosity may be affected by a number of factors such as pore sizes, pore shapes, distribution of pores, etc.

[0057] Depending on the application, the MSMA may be designed to have a relatively uniform size of pores following a uni-modal distribution or varying sizes of pores following a multi-modal distribution. In an embodiment, the casting mold may be made from spheroid-

shaped powders with similar diameters. Accordingly, after fabrication, the resulted MSMA may have spheroid-shaped pore structures with similar diameters. In alternative embodiments, the casting mold may be made from differently sized powders or components, thus the resulted MSMA may have differently sized pore structures. For example, the MSMA may be configured to have pore sizes in a bi-modal distribution, in which pores of a relatively larger size and a relatively smaller size may filter different fluids and particulates. Further, the casting mold may also be made from differently shaped powders or components, which leads to differently shaped pores. In practice, the geometry (including size and shape) of pores may change during expansion, and the degree of geometrical change may depend on a local strain level. Thus, to allow a consistent pore size across the range of expansion, differently sized and/or differently shaped pores may be used in an MSMA. Otherwise, the size of a pore throat may slightly change during expansion of the MSMA.

[0058] MSMAs are configured to exhibit strains under the influence of an applied magnetic field, which leads to changes in the dimension and/or volume of the MSMAs. For example, a tensile strain in one or more directions induced by the applied magnetic field may transition MSMAs to an expanded state, while a compressed strain in one or more directions may transition MSMAs to a compressed state. The strain may be a result of a martensitic phase transformation, which is a diffusionless displacive transformation. MSMAs may produce a phase transformation that is similar to other SMAs. However, traditional SMAs experience their phase transformation due to a temperature trigger or other suitable stimuli (e.g., electrical) while MSMAs experience their phase transformation due to a magnetic trigger.

[0059] When exposed to an external magnetic field, the MSMAs may be magnetized and generate an internal magnetic field. On a microscopic level, crystalline lattice structures of the MSMAs may be altered as by the internal magnetic field. Lattice structure in an austenite phase may be transformed to a martensite phase by going through a Bain distortion, wherein two or three axes are distorted such that the lattice symmetry is reduced. The Bain distortion may be followed by a lattice invariant shear, in which dislocations are formed at an interface of two crystal lattices. The dislocations facilitate the motion of twin boundaries, which may be responsible for the macro-scale magnetic-field-induced strains seen in MSMAs.

[0060] Further, an orientation of the magnetic field may impact the level of magnetic field-induced strain, since MSMAs carry anisotropy and its material properties have a directional

dependence. On a microscopic level, magneto crystalline anisotropy occurs when magnetic properties of the MSMA depend on a crystallographic direction. With magneto crystalline anisotropy, there may be a relatively "easy" and "hard" direction of magnetization that correlates to some crystallographic direction. The easy direction of magnetization may correspond to a long axis of a unit lattice structure, such that a lower magnetic field is needed to reach magnetization saturation. The hard direction of magnetization may correspond to a short axis of the unit lattice structure, such that a higher magnetic field is needed to reach magnetization saturation. Although a level of magnetization saturation may eventually be the same in the easy and hard directions of magnetization, given a sufficiently strong external magnetic field, the magnetization level at any field below saturation may be higher for the easy axis of magnetization. Consequently, it is possible that using a same strength of magnetic field, the magnetic field-induced strain may be minimal in the hard direction of magnetization but much higher in the easy direction of magnetization.

[0061] Utilizing the dependence of magnetic field-induced strain on an orientation of an applied magnetic field, an activated state and a deactivated state may be switched by rotating the applied magnetic field. For example, in the activated state, the magnetic field may be generally aligned with the easy direction of magnetization to induce significant strain (i.e., expanded state). In the deactivated state, the magnetic field may be rotated by generally 90 degrees, so that it may be generally aligned with the hard direction of magnetization to induce little to no strain (i.e. compressed state).

[0062] It should be understood that, since an MSMA may comprise a porous foam which is a polycrystalline structure, the lattice orientations may be more complex to determine than a single-crystal structure. For example, different grains of the foam may have different crystallographic orientations and/or different relative sizes. Consequently, there may be no uniform easy and/or hard directions of magnetization. In practice, optimal directions of magnetic field in the activated and deactivated states can be empirically determined. For example, strain levels may be tested with the magnetic field applied in all possible directions. Then, a maximum level may correspond to the activated state, and a minimal level may correspond to the deactivated state.

[0063] In an embodiment, to transition an MSMA between an activated state and a deactivated state, or vice versa, a trigger comprising a magnetic field may be provided by an

actuator comprising a magnetizer. In the activated state, the magnetizer may be configured to create a sufficiently strong magnetic field in an appropriate direction, such that the MSMA may be expanded to a desired degree. Upon application of the magnetic field, the MSMA may be almost instantly (or in a short time) transitioned to the activated state. Similarly to transition the MSMA material to the deactivated state, the magnetizer may be configured to create a sufficiently strong magnetic field in an appropriate direction (e.g., perpendicular to the original magnetic field), such that the MSMA may be relatively compressed to a desired degree. Being relatively compressed may include herein expansion to a lesser degree, recovering to a natural state, or compressed even more in comparison with the activated state. Since the magnetizer may be manipulated for a plurality of times, the MSMA may be activated and/or deactivated for a plurality of times. In other words, the actuation may be reversible.

[0064] To perform actuation, the magnetizer may be deployed into a wellbore using any technique. For example, the magnetizer may be coupled to a ball or a dart, which may be dropped in the wellbore to initiate an expansion process as needed. For another example, the magnetizer may be deployed into the wellbore via a length of slickline, wireline, and/or coiled tubing which is controlled from the rig surface. In some embodiments, the magnetizer may comprise an electromagnet formed as part of the well screen assembly that can be selectively activated to actuate the SMA material.

[0065] The magnetizer may comprise at least one permanent magnet, or at least one electromagnet, or any combination thereof. A permanent magnet may be made of any of a number of materials, such as iron, nickel, steel, cobalt, rare-earth metal alloys, ceramic magnets, nickel-iron alloys and/or rare-earth magnets such as a Neodymium magnet and a Samarium-cobalt magnet, or other known materials such as Co-netic AA ®, Mumetal ®, Hipernon ®, Hy-Mu-80 ®, Permalloy ® which all may comprise about 80% nickel, 15% iron, with the balance being copper, molybdenum, or chromium. The electromagnet may comprise an electrical coil connected to a current source. To increase a magnetic flux of an electromagnet, a permanent magnet or a ferromagnetic material may also be disposed within an electrical coil. According to Ampere's Circuital Law, the electric coil may produce a temporary magnetic field when an electric current flows through it. The magnetic field may disappear when the current stops. With the application of a direct current (DC), the electric coil may form a magnetic field of constant polarity. When the DC reverses direction, so does the magnetic polarity. The electric

coil may be a conventional coil (e.g., a solenoid) with a plurality of turns of a wire arranged side-by-side. Alternatively, the electric coil may be a bifilar coil comprising two sets of closely-spaced parallel wire windings. Depending on application, any other variant of winding patterns may also be used in the design of the electric coil.

[0066] A power source supplying current to the electric coil may comprise any device capable of being electrically coupled and/or providing power to the electric coil. In an embodiment, the power source may comprise a DC battery coupled to the electric coil that can be disposed at the surface and/or within the wellbore. Alternatively, the power source may be located on the rig surface. Current may be delivered to the electric coil through wireless power transmission or a power wireline connected to the electric coil. In addition, a downhole generator, such as a fluid turbine, may also be used to provide power to the electric coil.

[0067] In use, the magnetizer may not necessarily exclusively take the form of a solid component. If desired, the magnetizer may also comprise a ferromagnetic liquid or ferrofluid to facilitate applying a magnetic field to an MSMA. An embodiment of an MSMA actuation mechanism 700 is representatively illustrated in FIG. 8. Since some aspects of the MSMA actuation mechanism 700 may be similar to previously described well screen assemblies, the similar aspects will not be further described in the interest of conciseness. A magnetizer of the MSMA actuation mechanism 700 may comprise a magnet 702 and a ferromagnetic liquid 704, which together are configured to actuate an MSMA 706. The ferromagnetic liquid 704 may be contained in a housing 708, which is also coupled to the magnet 702 and the MSMA 706. The magnet 702 may comprise a permanent magnet and/or an electromagnet as described above. The ferromagnetic liquid 704 may be a colloidal liquid including a carrier fluid (usually an organic solvent or water) and a plurality of nanoscaled (or micronscaled) ferromagnetic particles suspended therein. The MSMA 706 may be a type of the SMA 202 described above, therefore descriptions regarding the SMA 202 may be applicable for the MSMA 706.

[0068] In an embodiment, the MSMA 706 and the magnet 702 may be placed on opposite sides of the base pipe 11, thus the magnet 702 and the ferromagnetic liquid 704 may form a magnetic circuitry configured to transition the SMA between an expanded state and a compressed state, or between the compressed state and the expanded state. The ferromagnetic liquid 704 may not need to be present in a deactivated state of the MSMA actuation mechanism 700. When the MSMA actuation mechanism 700 is to be activated downhole, the ferromagnetic

liquid 704 may be injected into the housing 708 via an opening or hole 710. The injection may be completed using any viable technique. After injection of the ferromagnetic liquid 704, the opening 710 may be closed or sealed. In the activated state, the MSMA 706 may expand outwardly toward the wellbore wall 212. Consequently, a space or gap between the MSMA 706 and the wellbore wall 212 may decrease. If desired, the MSMA 706 may contact the wellbore wall 212 to provide support for the formation 22.

[0069] In the MSMA actuation mechanism 700, the base pipe 11 may comprise any material, including a ferromagnetic material such as steel. Although a magnetic field generated by the magnet 702 alone may be blocked or shielded from the SMA 706 by a ferromagnetic base pipe, the use of the ferromagnetic liquid may allow the magnetic field to circumvent the ferromagnetic base pipe and reach the SMA 706. The greater flexibility in a material choice of the base pipe 11 may sometimes prove advantageous in applications.

[0070] In use, a degree of magnetic field induced strain may be affected by a variety of factors including, but not limited to, material composition, phase transformation, temperature, training, porosity, pore size, pore distribution, and pore architecture (e.g., uni-modal or bi-modal). To optimize an MSMA for a specific application, these factors may be configured to meet a certain requirement. For example, the strain response of the MSMA may be increased by operating the material close to a Curie temperature of the MSMA. The Curie temperature may be changed by alternating the relative mixture of the constituents in the MSMA and/or by altering cold working of the MSMA.

[0071] Sometimes before deploying an MSMA downhole, post-fabrication training may be used to tailor properties of the MSMA. Training may both enhance MFIS of the MSMA, or weaken MFIS of the MSMA if so desired. Training may take various forms, such as exposing the MSMA to many cycles of a rotating magnetic field, cycles of rising/falling temperatures, and/or cycles of loading/unloading mechanical strains or stresses. Based on different combinations of training mechanisms used, there may be magneto-mechanical, thermo-magnetic, and thermo magneto-mechanical training. For each trained MSMA, depending on a number of factors such as a composition and porosity of the MSMA, each training type may have a different impact on the MFIS. For example, for an MSMA comprising $Ni_{50.6}Mn_{28}Ga_{21.4}$ with 53% porosity, a number of thermo-magnetic training cycles may significantly enhance a maximum strain level (e.g., from 0.0002% to 0.07% which is a 34 fold increase). For another

MSMA comprising $Ni_{52.3}Mn_{24.3}Ga_{21.4}$ with 62.7% porosity, the thermo-magnetic training may enhance the maximum strain level to a lesser degree (e.g., from 0.09% to 0.275% which is a 3 fold increase). For another example, for another MSMA comprising $Ni_{52.3}Mn_{24.3}Ga_{21.4}$ with 62.4% porosity, a number of thermo magneto-mechanical training cycles may also enhance the maximum strain level (e.g., from 2.1% to 8.7% which is a 4 fold increase). It may be noted that the maximum strain level may vary widely based on a number of factors described above. For some Ni-Mn-Ga MSMAs, the maximum MFIS may be configured to reach up to 10%.

[0072] While MSMAs are described above as an example, it should be understood that other types of SMAs may be similarly implemented without departing the principles of the present disclosure. In an embodiment, an SMA material may comprise a material (e.g., a porous foam) that responds to a trigger comprising a temperature change. The trigger may be provided by an actuator comprising a heating/cooling fluid circuitry. In implementation, a cold fluid may be circulated into the wellbore prior to disposing the SMA material in the wellbore. Then, after the SMA material is deployed into the wellbore, the fluid may be heated and/or the heat from the formation may heat the SMA material, thereby transitioning the SMA material from a deactivated state to an activated state. If the SMA material needs to be transitioned back to the deactivated state, the cold fluid may be circulated again. In an embodiment, an SMA material may also comprise a porous foam that responds to a trigger comprising a mechanical stress. In this case, the SMA material may be pre-stressed during installation on the rig surface. After the SMA material is deployed downhole, it may be activated by a release mechanism to an expanded state.

[0073] It should also be noted more than one type of trigger may be used to transition an SMA. For example, an MSMA described above may be triggered by using a combination of at least one magnetic field, temperature change, and/or mechanical stress. If the MSMA is pre-stressed during installation on the rig surface, a larger expansion may be allowed when the MSMA is activated for the first time in the wellbore. Additionally, the SMA may be actuated or transitioned for any number of times during its course of operation downhole. The SMA may remain downhole for any period of time before it is retrieved back to the rig surface in a deactivated state. If desired, the SMA may be configured to remain downhole with reversible actuations for the life of the well.

[0074] Having described the various systems and method, various embodiments may include, but are not limited to:

[0075] In an embodiment, a well screen assembly for use in a wellbore comprises a base pipe comprising one or more fluid passageways, and a shape-memory alloy disposed about the base pipe. The one or more fluid passageways are configured to provide fluid communication between an exterior of the base pipe and a central flowbore, and the shape-memory alloy is configured to transition between an expanded state and a compressed state in response to a trigger. The well screen assembly may also include a filter element disposed about the base pipe. The shape-memory alloy may be disposed between the base pipe and the filter element, and the shape-memory alloy may be configured to expand the filter element when transitioned to the expanded state. The well screen assembly may also include a filter element disposed about the base pipe, and the filter element may be disposed between the base pipe and the shape-memory alloy. The shape-memory alloy may be configured to engage a wellbore wall and the filter element when in the expanded state. The well screen assembly may also include a shroud disposed about and coupled to the base pipe. The shape-memory alloy may be coupled to the shroud between the shroud and the base pipe, and the shape-memory alloy may be configured to expand radially inward when transitioned from the compressed state to the expanded state. The shape-memory alloy may be coupled to an outer surface of the shroud, and the shape-memory alloy may be configured to expand radially outward when transitioned from the compressed state to the expanded state. The shape-memory alloy may be configured to filter a fluid flowing from the exterior of the base pipe to the central flowbore. The shape-memory alloy may comprise a metal foam, and the metal may comprise at least one metal selected from the group consisting of: nickel, manganese, gallium, any alloy thereof, and any combination thereof. The trigger may comprise a change in temperature of the shape-memory alloy. The shape-memory alloy may comprise a magnetic shape-memory alloy, and the trigger may comprise at least one magnetic field. The at least one magnetic field may be generated by a permanent magnet, an electromagnet, or any combination thereof. The well screen assembly may also include an actuator configured to provide the trigger to transition the shape-memory alloy between the expanded state and the compressed state, or between the compressed state and the expanded state. The actuator may comprise a magnetizer configured to expand the shape-memory alloy in an activated state and compress the shape-memory alloy in a deactivated state, and the

magnetizer may create a magnetic field in the activated state. The magnetizer may at least partially cancel the magnetic field in the deactivated state. The magnetizer may comprise an electromagnet or a combination of the electromagnet and a permanent magnet disposed about the electromagnet. The actuator may comprise a first magnetizer configured to expand the shape-memory alloy by creating a first magnetic field, and a second magnetizer configured to compress the shape-memory alloy by creating a second magnetic field generally perpendicular to the first magnetic field. The first magnetizer may comprise a first permanent magnet, and the second magnetizer may comprise a second permanent magnet. The actuator may comprise a mechanical control mechanism configured to release stored mechanical energy of the shape-memory alloy in the expanded state. The shape-memory alloy may comprise a corrugated structure, and/or the shape-memory alloy may comprise a plurality of pores. Each pore may have a pore size, and the pore size of each port of the plurality of pores may comprise one of a uni-modal distribution or a multi-modal distribution. The well screen assembly may also include one or more chemical components disposed within one or more of the plurality of pores, and the one or more chemical components may comprise solid particulates. The one or more chemical components may comprise at least one component selected from the group consisting of: an organic acid, an inorganic acid, an inorganic acid salt, a fluid loss control additive, a scale inhibitor, a corrosion inhibitor, a catalyst, a clay stabilizer, a biocide, a bactericide, a friction reducer, an iron control agent, a solubilizer, a pH adjusting agent, a gel breaker, and any combination thereof. The base pipe may comprise a non-magnetic material, and the base pipe may comprise aluminum, carbon fiber, a polymer, or any combination thereof.

[0076] In an embodiment, a well screen assembly for use in a wellbore comprises a wellbore tubular string comprising a first screen assembly coupled to a second screen assembly, and a shape-memory alloy disposed about the wellbore tubular string. The shape-memory alloy is configured to provide a selectable resistance to axial flow along an exterior of the wellbore tubular string between the first screen assembly and the second screen assembly. The shape-memory alloy may be configured to transition between an expanded state and a compressed state in response to a trigger. The shape-memory alloy may be configured to provide an increased resistance to axial flow by transitioning to a compressed state, the shape-memory alloy may comprise a porous material, and the shape-memory alloy may comprise smaller pores in the compressed state than the expanded state. The shape-memory alloy may be configured to

provide an increased resistance to axial flow by expanding to contact a wellbore wall, and the shape-memory alloy may be configured to provide a decreased resistance to axial flow by compressing to provide a flow channel between the shape-memory alloy and the wellbore wall.

[0077] In an embodiment, a well screen assembly for use in a wellbore comprises a base pipe comprising one or more fluid passageways, and a shape-memory alloy disposed in a flow path between the exterior of the base pipe and the central flowbore. The one or more fluid passageways are configured to provide fluid communication between an exterior of the base pipe and a central flowbore, and the shape-memory alloy is configured to provide a first resistance to flow in a compressed state and a second resistance to flow in an expanded state. The first resistance to flow may be greater than the second resistance to flow. The shape-memory alloy may be disposed about at least a portion of the base pipe. The shape-memory alloy may be disposed in a flow restrictor, and/or the shape-memory alloy may be disposed in one or more of the one or more fluid passageways. The well screen assembly may also include an actuator configured to transition the shape-memory alloy between the expanded state and the compressed state, or between the compressed state and the expanded state. The actuator may comprise a magnetizer, and the magnetizer may comprise a ferromagnetic liquid and a permanent magnet. The shape-memory alloy and the permanent magnet may be placed on opposite sides of the base pipe, and the ferromagnetic liquid and the permanent magnet may form a magnetic circuitry configured to transition the shape-memory alloy between the expanded state and the compressed state, or between the compressed state and the expanded state. The shape-memory alloy may comprise a porous filter media, and the porous filter media may comprise a first layer and a second layer, where the first layer may comprise a larger pore size than the second layer.

[0078] In an embodiment, a method comprises providing a trigger to a shape-memory alloy disposed about a base pipe in a wellbore, transitioning the shape-memory alloy from a compressed state to an expanded state in response to the trigger, and establishing fluid communication between an exterior of the base pipe and a central flowbore. The base pipe comprises one or more fluid passageways configured to provide fluid communication between the exterior of the base pipe and the central flowbore. The method may also comprise expanding a filter element disposed about the base pipe in response to the transitioning. The method may also comprise engaging a wellbore wall with the shape-memory alloy in the expanded state. The method may also comprise filtering a fluid flowing between the exterior of the base pipe and the

central flowbore using the shape-memory alloy. Providing the trigger may comprise providing at least one of a magnetic field or temperature controlled fluid to the shape-memory alloy. The method may also comprise training the shape-memory alloy by exposure to a plurality of temperatures, application of a mechanical stress, application of a magnetic field, or any combination thereof. The method may also comprise releasing one or more chemical components in response to transitioning the shape-memory alloy from the compressed state to the expanded state.

[0079] In an embodiment, a method comprises providing a trigger to a shape-memory alloy disposed in a fluid pathway between an exterior of a base pipe and a central flowbore, transitioning the shape-memory alloy from a compressed state to an expanded state in response to the trigger, and changing a fluid resistance through the fluid pathway in response to the transitioning. The shape-memory alloy may be disposed about the base pipe. The shape-memory alloy may be disposed in a fluid restriction, and the fluid restriction may be disposed in the fluid pathway. Changing the fluid resistance may comprise substantially preventing flow through the fluid pathway. The shape-memory alloy may comprise a porous metal foam, and the shape-memory alloy may be a magnetic shape-memory alloy. The trigger may comprise at least one magnetic field generated by a permanent magnet, an electromagnet, or any combination thereof. At least a portion of the fluid pathway may comprise an axial flowpath along the exterior of the base pipe, and changing the fluid resistance through the fluid pathway may comprise changing a resistance to flow along the axial flowpath.

[0080] At least one embodiment is disclosed and variations, combinations, and/or modifications of the embodiment(s) and/or features of the embodiment(s) made by a person having ordinary skill in the art are within the scope of the disclosure. Alternative embodiments that result from combining, integrating, and/or omitting features of the embodiment(s) are also within the scope of the disclosure. Where numerical ranges or limitations are expressly stated, such express ranges or limitations should be understood to include iterative ranges or limitations of like magnitude falling within the expressly stated ranges or limitations (e.g., from about 1 to about 10 includes, 2, 3, 4, etc.; greater than 0.10 includes 0.11, 0.12, 0.13, etc.). For example, whenever a numerical range with a lower limit, R_l, and an upper limit, R_u, is disclosed, any number falling within the range is specifically disclosed. In particular, the following numbers within the range are specifically disclosed: $R=R_l+k*(R_u-R_l)$, wherein k is a variable ranging

from 1 percent to 100 percent with a 1 percent increment, i.e., k is 1 percent, 2 percent, 3 percent, 4 percent, 5 percent, ..., 50 percent, 51 percent, 52 percent, ..., 95 percent, 96 percent, 97 percent, 98 percent, 99 percent, or 100 percent. Moreover, any numerical range defined by two R numbers as defined in the above is also specifically disclosed. Use of the term "optionally" with respect to any element of a claim means that the element is required, or alternatively, the element is not required, both alternatives being within the scope of the claim. Use of broader terms such as comprises, includes, and having should be understood to provide support for narrower terms such as consisting of, consisting essentially of, and comprised substantially of. Accordingly, the scope of protection is not limited by the description set out above but is defined by the claims that follow, that scope including all equivalents of the subject matter of the claims. Each and every claim is incorporated as further disclosure into the specification and the claims are embodiment(s) of the present invention.

CLAIMS

What is claimed is:

1. A well screen assembly for use in a wellbore comprising:

a base pipe comprising one or more fluid passageways, wherein the one or more fluid passageways are configured to provide fluid communication between an exterior of the base pipe and a central flowbore; and

a shape-memory alloy disposed about the base pipe, wherein the shape-memory alloy is configured to transition between an expanded state and a compressed state in response to a trigger.

2. The well screen assembly of claim 1, further comprising a filter element disposed about the base pipe, wherein the shape-memory alloy is disposed between the base pipe and the filter element, and wherein the shape-memory alloy is configured to expand the filter element when transitioned to the expanded state.

3. The well screen assembly of claim 1, further comprising a filter element disposed about the base pipe, wherein the filter element is disposed between the base pipe and the shape-memory alloy.

4. The well screen assembly of claim 3, wherein the shape-memory alloy is configured to reduce a distance between a wellbore wall and the filter element when transitioned from the compressed state to the expanded state.

5. The well screen assembly of claim 1, further comprising a shroud disposed about and coupled to the base pipe.

6. The well screen assembly of claim 5, where the shape-memory alloy is coupled to the shroud between the shroud and the base pipe, and wherein the shape-memory alloy is configured to expand radially inward when transitioned from the compressed state to the expanded state.

7. The well screen assembly of claim 5, wherein the shape-memory alloy is coupled to an outer surface of the shroud, and wherein the shape-memory alloy is configured to expand radially outward when transitioned from the compressed state to the expanded state.

8. The well screen assembly of claim 1, wherein the shape-memory alloy is configured to filter a fluid flowing from the exterior of the base pipe to the central flowbore.

9. The well screen assembly of claim 1, wherein the shape-memory alloy comprises a metal foam.

10. The well screen of assembly claim 1, wherein the trigger comprises a change in temperature of the shape-memory alloy.

11. The well screen assembly of claim 1, wherein the shape-memory alloy comprises a magnetic shape-memory alloy, and wherein the trigger comprises at least one magnetic field.

12. The well screen assembly of claim 11, wherein the at least one magnetic field is generated by a permanent magnet, an electromagnet, or any combination thereof.

13. A method comprising:

providing a trigger to a shape-memory alloy disposed about a base pipe in a wellbore, wherein the base pipe comprises one or more fluid passageways configured to provide fluid communication between an exterior of the base pipe and a central flowbore;

transitioning the shape-memory alloy from a compressed state to an expanded state in response to the trigger; and

establishing fluid communication between the exterior of the base pipe and the central flowbore when the shape-memory allow is in the expanded state.

14. The method of claim 13, further comprising expanding a filter element disposed about the base pipe in response to the transitioning.

15. The method of claim 13, further comprising engaging a wellbore wall with the shape-memory alloy in the expanded state.

16. The method of claim 13, further comprising filtering a fluid flowing between the exterior of the base pipe and the central flowbore using the shape-memory alloy.

17. The method of claim 13, further comprising training the shape-memory alloy by exposure to a plurality of temperatures, application of a mechanical stress, application of a magnetic field, or any combination thereof.

18. The method of claim 13, further comprising releasing one or more chemical components in response to transitioning the shape-memory alloy from the compressed state to the expanded state.

19. A method comprising:

providing a trigger to a shape-memory alloy disposed in a fluid pathway between an exterior of a base pipe and a central flowbore;

transitioning the shape-memory alloy from a compressed state to an expanded state in response to the trigger; and

changing a fluid resistance through the fluid pathway in response to the transitioning.

20. The method of claim 19, wherein the shape-memory alloy is disposed in a fluid restriction, wherein the fluid restriction is disposed in the fluid pathway.