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Modular, pre-tensioned, self-cleaning screening panels

Abstract

A modular, pre-tensioned, self-cleaning screening panel having a frame and at least one pre-tensioned wire that is fastened to the frame.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This is a continuation application that claims priority to commonly assigned, co-pending U.S. application Ser. No. 17/194,816, filed, Mar. 8, 2021, which claims priority to U.S. Provisional Patent Application No. 62/986,304, filed on Mar. 6, 2020, the entire disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

(1) This application is directed toward a screening panel used, for example, with a screening machine of the type used to separate or classify mixtures of solid particles of different particle sizes into classes of different sizes. In most instances, the screening panel is removably attached to a vibratory screening machine.

BACKGROUND OF THE INVENTION

(2) The screening machine can be used, for example, in the aggregate industry or in mining industries. The aggregate and mining industries utilize many types of machines to sort aggregates by size. Most such machines include a screening surface that includes a plurality of holes or openings. The machines utilize vibratory motions, defined below, to agitate a mixture of aggregates placed on the screening surface, to promote separation through the openings. Sorting is achieved by undersized particles passing through the openings in the screening surface and the oversize particles being retained above the screen surface. These machines usually have some type of vibrating mechanism to shake the unit and its screening surfaces. The vibrating mechanisms usually include an unbalanced weight mounted on one or several rotating shafts which, when rotated, force a cycling motion into the screen machine. The resulting motion can have a circular path, linear path, elliptical path, or any combination of those shapes. Another type of conventional machine is a trommel or rotatory screening machine that separates materials using rotation. In these machines, round screens are disposed in a rotating drum, with the material to be sorted by the screens moving via the rotation of the drum.

(3) Machines of the type just described can be configured to accept different types of screen media. One conventional type of screen is a hooked screen panel that includes a plurality of wires generally parallel to each other. Opposite ends of the wires are provided with hooks or angled features. The hooks are coupled to a movable feature on a machine of the type described, and this movable feature is moved to tension the wires at installation/replacement of the screen. The tensioned wires then provide the screening surface. Of course, tensioning the screen panel of the type just described is a time-consuming and laborious process, usually requiring multiple installers.

(4) Other types of vibratory machines of the type described above are configured to receive modular screens as screening media. As used herein, "modular screens" generally refers to screens having a specific size, shape, mounting features and/or configuration. Unlike the panel screens described above, modular screens may have a fixed sized and/or shape, such that the screen material that sorts the aggregate is not and/or cannot be adjusted. Modular screens may have a fixed outer frame that is received in a receptacle of the vibratory machine. Some example modular screens may be over-molded with a polymer such as urethane or rubber to facilitate coupling of the screen to the machine and/or to promote movement of aggregate across the screening surface. The polymer material is used to attach the screen panel to the screen machine, and often to also create the openings in the screen area. Modular screens typically require only a single installer with minimal training and time, and thus offer improvements over the screen panels discussed above.

(5) Some conventional modular screen panels use aligned, un-tensioned wires to form the screening surface. In these examples, the wires are formed in a generally parallel arrangement, generally as in the screen panels discussed above. However, because the modular frame has a fixed size, the wires in these conventional screens cannot be tensioned later. They are not tensioned at all. Because of this lack of tension, previous arrangements have been fabricated only using relatively larger diameter or gauge wire, because of the higher rigidity of these wires. Alternatively, or additionally, such screens have required additional supports to provide the rigidity lacking from the untensioned wires. However, these intermediate supports reduce throughput of the modular screen.

(6) Other conventional screen panels can include woven wire mesh as the screening surface, instead of the generally parallel wires. Wire mesh, however, has well known drawbacks. For example, pieces of the aggregate being sorted by the mesh can become lodged in openings in the

mesh. These lodged pieces reduce throughput of the machine, and clearing such plugged pieces typically requires extra tools, for example a ball tray, and/or extra labor.

(7) Thus, each of the conventional screen types described above has drawbacks. For example, the hook screen panel requires additional labor and expertise to install the screen on a vibratory machine. Modular screens with wire screening arrangements use untensioned wires, which limits the functionality and/or types of screens that can be fabricated. Mesh screens are prone to clogging.

(8) This disclosure provides improvements in screening media used with vibratory machines.

SUMMARY OF THE INVENTION

(9) Screening panels are disclosed, along with machinery to manufacture the screening panels and methods to manufacture the screening panel.

(10) In one example, a screening panel includes a frame and a plurality of wires. The frame includes a first frame end spaced from a second frame end in a longitudinal direction and a first frame side spaced from a second frame side in a lateral direction. The wires extend from the first frame end to the second frame end. Individual of the plurality of wires are coupled proximate a first wire end to the first frame end and are coupled proximate a second wire end to the second frame end. The plurality of wires are in tension between the first wire end and the second wire end and are configured to vibrate independently of each other.

(11) An example method of manufacturing a screening panel includes providing a plurality of wires, the plurality of wires extending generally from first wire ends to second wire ends in a longitudinal direction. Adjacent wires of the plurality of wires are arranged to provide a spacing therebetween. The method also includes providing a frame comprising a first frame end spaced from a second frame end in the longitudinal direction and a first frame side spaced from a second frame side in a lateral direction. The method also includes at least one of tensioning the wires in the longitudinal direction or compressing the frame in the longitudinal direction, and with the at least one of the plurality of wires tensioned in the longitudinal direction or the frame compressed in the longitudinal direction, securing the first wire ends of the plurality of wires to the first frame end and securing the second wire ends of the plurality of wires to the second frame end. The method also includes releasing the at least one of the tensioning or the compressing with the wires secured to the frame to provide a screening panel with tensioned wires in which the wires are configured to vibrate independently of each other.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIGS. 1A-1F illustrate various prior art wire configurations used in screening panels.

(2) FIG. 2 illustrates a frame.

(3) FIG. 3 illustrates a cross-section of FIG. 2 taken along the lines 3-3.

(4) FIG. 4 illustrates a frame with tensioned wires converted into a screening panel.

(5) FIG. 5 illustrates a dual carriage device having a frame carriage compressing unit and a screen tensioning unit.

(6) FIG. 6 illustrates an enlarged view of FIG. 3 taken along the line 6-6.

(7) FIGS. 7A and 7B illustrate examples of cut wires from un-tensioned wires (FIG. 7A) and tensioned wires (FIG. 7B).

(8) FIG. 8A illustrates how the adhesive encapsulates a wire in one embodiment and FIG. 8B illustrates how the adhesive encapsulates a wire in another embodiment.

(9) FIG. 9 illustrates a flow chart of manufacturing a screening panel.

DETAILED DESCRIPTION OF THE INVENTION

(10) As illustrated at FIG. 2, this application relates to a screening panel **100** including a frame **110** and a plurality of wires **130** secured to the frame (see, FIG. 4) wherein the plurality of wires **130**

contains at least one pre-tensioned wire.

(11) The frame **110** has a first attachment frame end **112**, a second attachment frame end **114** spaced in a longitudinal direction from the first attachment frame end **112**. The frame **110** also has a first frame side **116** and a second frame side **118** spaced from the first frame side **116** in a lateral direction. The first attachment frame end **112**, the second attachment frame end **114**, the first frame side **116**, and the second frame side **118** are connected to define the frame's outer perimeter **900** and the frame's inner perimeter **902**. The frame's inner perimeter **902** defines a screen spacing area **120**. In examples, the wires **130** are positioned within the screen spacing area **120**.

(12) As also shown in FIG. 2, the wires **130** are secured at a first wire end to the first attachment frame end **112** and at a second wire end to the second attachment frame end **114**. The wires are illustrated as a plurality of parallel wires extending in the longitudinal direction. The wires are spaced from each other, e.g., from an adjacent wire, in the lateral direction by a predefined distance and/or in a predetermined way. Together, the wires **130** define a plurality of openings sized and/or shaped to selectively permit material of a certain size (or smaller) to pass therethrough.

(13) In examples, the wires **130** may be arranged in a number of configurations in which the opposite ends of the wires are fixed to the attachment frame ends **112**, **114**. Examples of numerous wire configurations that can be used for the wires **130** are shown in FIGS. 1A-1F. These configurations include and are not limited to (1) a harp screen configuration, (2) a herringbone configuration (L-configuration), (3) a square configuration (M-configuration), (4) a double-square configuration (M-2 configuration), (5) a triangle configuration (H configuration), and (6) a clean slot configuration.

(14) The harp screen configuration, as illustrated at FIG. 1A, illustrates straight wires wherein each wire **15** is essentially parallel with each adjacent wire. The wires **130** in FIG. 2 are generally configured in the harp screen configuration.

(15) The herringbone configuration, as illustrated at FIG. 1B, has a plurality of wires wherein each wire **6** (a) has the same zig-zag pattern and (b) is essentially parallel with each adjacent wire.

(16) The square configuration, as illustrated at FIG. 1C, has a plurality of wires wherein (a) each wire has a zig-zag pattern having a plurality of apex locations **10** and a plurality of nadir locations **12**, and (b) each wire's apex location **10** is positioned to contact or nearly contact a second, adjacent wire's nadir location **12** and each first wire's nadir location **12** is positioned to contact or nearly contact an adjacent wire's apex location **10** to create a square or rectangular spacing **16** between the adjacent wires.

(17) The double square configuration, as illustrated at FIG. 1D, is a variation of the square configuration. Each wire set **144**, **144'**, **144''** is two parallel or essentially parallel wires wherein each wire in the wire set has a zig-zag pattern having a plurality of apex locations **10** and a plurality of nadir locations **12**. A second wire set's **144'** apex location **10** is positioned to contact or nearly contact the third wire set's **144''** nadir location **12** and the second wire set's **144'** nadir location **12** is positioned to contact or nearly contact the first wire set's **144** apex location **10** to create a square or rectangular spacing **16** between the adjacent wire sets.

(18) The triangle configuration, as illustrated at FIG. 1E, is a variation of the square configuration, with a straight wire **8** positioned between zig-zag wires **14**.

(19) The clean slot configuration, as illustrated at FIG. 1F, is an alternative version of the harp configuration in that every straight wire **8** is adjacent to a crimped wire **9**.

(20) In examples of this disclosure, the wires **130** are arranged in the screen spacing area **120**, e.g., in a configuration such as one of the configurations of FIGS. 1A-1F. As noted above, the wires **130** are attached at opposite ends to the attachment frame ends **112**, **114** in the desired configuration. Each of the wires **130** is spaced laterally from adjacent wires. Unlike in a mesh, the wires **130** are not supported by interwoven, laterally disposed wires.

(21) The wires **130** may be arranged to have self-cleaning properties. For example, a self-cleaning screen has openings that can vary slightly in size or shape. For instance, in examples described

herein, the wires **130**, or at least portions of the wires, are allowed to vibrate independently, e.g., relative to each other, to slightly vary the size of the openings defined by adjacent wires. For instance, the wires **130** of the present disclosure are fixed at their ends and are not otherwise constrained along their length. In other instances, motion of the wires **130** may be minimally constrained between their ends, e.g., at a point of contacting the support member **150**, at a point of contact with one or more other support members, one or more laterally-extending wires, or the like. Stated differently, the wires **130** or portions of the wires are allowed to vibrate to slightly vary openings between the wires **130**. By slightly increasing the size of an opening, a lodged or wedged material may become dislodged. In contrast, conventional non-self-cleaning screens have openings that are generally fixed, e.g., by the nature of a weave, welding, molding or perforations in a sheet or plate.

(22) The screening panel **100** can also have an interconnecting structure **352**, made of conventional screening panel materials such as and not limited to metallic material like steel, or a polymeric material like urethane or rubber, or combinations thereof positioned over the frame **110** so the interconnecting structure **352** is formed so the screening panel **100** can be, preferably easily, removably attached to a specific screening machine (not shown). The interconnecting structure **352** can be any shape that fits a specific screening machine. More specifically, the screening panel **100** has a generally fixed size and shape defined by the frame **110** and/or the interconnecting structure **352**. The size and shape are generally fixed or predefined to facilitate attachment of the panel to a receptacle or cooperating features of a vibratory machine. The term “modular” may be used herein to generally refer to such panels having a fixed size, shape and/or arrangement of attachment features.

(23) Collectively, the frame's interior perimeter—delineated by the first attachment frame end **112**, the second attachment frame end **114**, the first frame side **116**, and the second frame side **118**—defines the screen spacing area **120**. Likewise, the panel's interior perimeter—delineated by the interconnecting structure **352** (a) over the frame **110**; (b) under the frame **110**; (c) on the frame's outer perimeter **900**, (d) on the frame's interior perimeter **902**, or (e) combinations thereof—defines the panel spacing **320**. The screen spacing area **120** and the panel spacing **320** can be the same size or different size especially if the interconnecting structure is positioned on the interior perimeter **902**.

(24) Un-tensioned and tensioned are terms dependent on how a wire reacts when cut in (a) the screen spacing if the frame **110** is exposed or (b) the panel spacing **320** if the interconnecting structure **352** is formed.

(25) FIG. 7A illustrates tensioned wires **950**, **952**, and **954**, as in examples of our invention, interconnected to a frame (not shown) prior to cutting the wire (left side) and after cutting the wire (right side). The tensioned wires **950**, **952**, and **954** were scored (or marked) in the same horizontal plane **956**. In the illustrated example, the horizontal plane **956** provides a reference line extending laterally across the array of wires. After marking the tensioned wires, Applicant cut wire **952** at **970**. As illustrated, a reference line **962** on cut tensioned wire **952** noticeably moved away (as shown in FIG. 7A the distance Y) from the horizontal plane **956** while the uncut tensioned wires **950**, **954** remain in their original positions. With a tensioned wire, the measured distance Y between two marks on the wire decreases if the tension in the wire is removed by cutting at a spot not between the two marks. It is understood to those skilled in the art that a suitably accurate measurement between two marks on a wire can be accomplished by various methods such as CMM or optical device with the two marks spaced significantly apart and the central axis of the wire aligned with a straight line. Further, it is understood that the decrease is relative to the wire's cross-sectional area. That means that a tensioned wire having a cross sectional area of, for example, 1 mm.² will be significantly decreased compared to a wire having a cross-section area of, for example, 10 mm.².

(26) In contrast, FIG. 7B illustrates un-tensioned wires, including wires **910**, **912**, and **914**, as in

some conventional arrangements, interconnected to a frame (not shown) prior to the cutting the wire (left side) and after cutting the wire (right side). The un-tensioned wires **910**, **912**, and **914** were scored (or marked) in the same horizontal plane **956**). After scoring the un-tensioned wires, Applicant cut wire **912** at **930**. As illustrated, the score line **922** on cut un-tensioned wire **912** (also illustrated at line **926**) and the score lines **920**, **924** on uncut un-tensioned wires **910**, **914** remained essentially in the same horizontal plane **936** and location as identified by the distance Z. With an un-tensioned wire, a measured distance between two marks on the wire does not materially change if the wire is cut at a spot not between the two score marks.

(27) Stated differently, when a tensioned wire of the wires **130** is cut or breaks, the tension in the wire causes the segments on either side of the cut to appreciably shorten or recoil. In contrast, untensioned wires, as in conventional arrangements, do not appreciably move.

(28) The first attachment frame end **112** and the second attachment frame end **114** can each have an upper bond area **122** and a lower bonding surface **124**, as illustrated at FIG. 3 and the magnified view of FIG. 6. (Note that in FIG. 3, the wires **130** are omitted for clarity.) The upper bond area **122** is positioned adjacent to the frame's interior perimeter **902** while the lower bonding surface **124** is positioned adjacent to the frame's exterior surface **900**. The upper bond area **122** and the lower bonding surface **124** can be (a) two different pieces or (b) machined from a single piece. As illustrated at FIG. 6, the frame **100** has a base level **800**, a first level **802** that is equal to the height of the lower bonding surface in relation to the base level, a second level **804** that is equal to the height of the upper bond area in relation to the base level, and a third level **806** that is equal to the height of the first frame side (and the second frame side) in relation to the base level. It is understood that the third level is above the second level, the second level is above the first level and the first level is above the base level.

(29) Although the frame **110** is illustrated as having a rectangular shape, the frame **110** is not limited to this shape. For example, the frame **110** may be square, ovular, circular, have rounded features, or the like. Any shape that allows for tensioning of the wires **130** as in examples described herein is contemplated.

(30) The lower bonding surface **124** is configured to receive an adhesive **198** that secures the wires **130** to the frame **110** while the first frame side **116**, and second frame side **118** are designed to have no adhesive thereon since the first frame side **116**, and second frame side **118** do not normally secure any wire to the frame **110** or panel **100**. Examples of the adhesive can be UV cured methyl methacrylate or acrylic ester, such as and not limited to Loctite's HH8003 or AA312 industrial adhesive material manufactured by the Henkel Corporation of Düsseldorf, Germany. Obviously, the adhesive could be altered to other adhesives like epoxy materials. It is also understood that alternative methods such as welding, sonic welding, screws, magnets, bending, nuts and bolts and combinations thereof can also be used to secure the tensioned wires to the frame. When the alternative method to secure the tensioned wires to the frame is used, it is preferable to weld the tensioned wires to the frame on the upper bond area **122**, the lower bonding surface **124** and combinations thereof. In some examples, the upper bond area **122** is not necessary.

(31) In any case, when an adhesive material is used, the upper bond area **122** inhibits the adhesive material from leaking into the screen spacing **120** and ensures the wires **130** remain in or near (in many instances, slightly above as a result of size constraints) a neutral axis of bending **132** (defined below) with the frame **110**. The upper bond area **122** also provides the adhesive support against shear forces on the first attachment frame end's **112** and the second attachment frame end's **114** top surface **940** (illustrated at FIG. 6) and requires the adhesive **198** fails in tension upward before shear becomes an issue.

(32) As previously expressed, the frame **110** has the first attachment frame end **112**, the second attachment frame end **114**, the first frame side **116**, and the second frame side **118**. Likewise, it is possible that the frame **110** can have one or more additional support members to enhance the rigidity of the frame **110** and/or to further support the wires **130**. For example, and as illustrated at

FIGS. 2 and 3, the frame **110** can include a support bar **150** extending laterally, e.g., generally parallel to the first attachment frame end **114** and the second attachment frame end **114**. Although a single support bar **150** is illustrated, more than one support bar **150** may be provided. Moreover, in some instances the support bar **150** may not be required. Reducing the number of support bars **150** may be beneficial, e.g., because each support bar reduces the effective screening area of the screening panel. The support bar **150** may provide support to (a) the frame **110** when the frame **110** is compressed (illustrated by arrow **200**) during the manufacturing process of the screening panel **100** or (b) the screening panel when the screening panel **100** experiences vibration forces by the screening machine. In particular, each support bar **150** extends from the first frame side **116** to the second frame side **118** to inhibit the frame **110** or screening panel **100** from bending (illustrated by arrow **202**) or bowing too much when the frame **110** is being compressed during the manufacturing of the screening panel **100** or the screening panel is vibrated by a screening machine.

(33) The support bar **150** is one example of a support member that enhances the rigidity of the frame **110**. In other examples, the frame **110** can include other support members, including but not limited to one or more longitudinally extending support members, e.g., positioned between and parallel to the first frame side **116** and the second frame side **118**. Other support members can include angled or oblique support members. As noted above, the frame **110** may include no additional support member.

(34) When a support member, like the support bar **150**, is provided in the screening area, the wires **130** may contact the support member. In some examples, the wires **130** may be fixed or attached to the support member, using welding, adhesive, or the like. Even when attached to the support member, the wires **130** are able to vibrate to provide the self-cleaning properties discussed above. For instance, a sufficient amount of the wires **130** extends between the support bar **150** and the frame ends **112**, **114** that is capable of independent vibration.

(35) The first frame side **116** and the second frame side **118** each have a neutral axis. The neutral axes of each the first and second frame sides are normally positioned at the halfway point of the height of the respective first and second frame side. The present invention directs the forces in the wires in the plane between the neutral axis of the first frame side **116** and the neutral axis of the second frame side **118** to decrease and inhibit bending the frame **100**. The plane positioned between the neutral axis of the first frame side **116** and the neutral axis of the second frame side **118** are referred to as the neutral axis of bending **132**. It is preferred, the wires **130** are designed to be positioned therein or near the neutral axis of bending **132**. The neutral axis of bending **132** is designed to be the location in which all forces applied to the screening panel **100** (and frame **110**) are supposed to be concentrated in order to minimize the bending of the screening panel **100** (and frame **110**).

(36) Tensioned wires are positioned in or near the neutral axis of bending **132** to decrease and/or inhibit the wires from bending up (arrow **202**) or down—depending on the tension—in the frame **110**. Likewise, the tensioned wires are in the neutral axis of bending **132** to inhibit the frame from bending up (arrow **202**) or down—depending on the tension.

(37) As previously addressed, this invention is directed to modular screens with tensioned wires. As detailed further herein, screens of this disclosure can be manufactured by tensioning wires and/or compressing a frame prior to fastening the wires to the frame. Applicants have confirmed through experimentation that if tensioned wires that are evenly tensioned or about evenly tensioned are applied to a non-compressed frame, then the resulting screening panel has wires positioned near the first and second frame sides retaining the desired tension while the remaining middle section wires lose tension as a result of the frame deflecting as a result of the tensioned wires. The lost tension of the middle section wires is significant because the middle section then does not function as an effective self-cleaning screen.

(38) Another advantage of the present invention is that tensioned wires applied to a compressed frame permits the screen spacing **120** to be maximized by minimizing the number of support bar(s)

150 and/or other support members, which may include supports that extend between the first frame end and the second frame, for instance, parallel to the first and second frame sides, except positioned in the screen spacing area **120**. Additional support members have been utilized in prior art screen frames of the same size. That being said, the support bar **150** and/or additional support member may be used in some screen frame embodiments of the present invention.

(39) To further assist in minimizing the bending of the screening panel **100**, the support bar **150** (and/or other support members) may be positioned proximate the neutral axis **132**. With this arrangement, the support bar **150** assists in directing any forces applied to the screening panel **100** into the neutral axis **132**. For instance, the support bar **150** may resist lateral displacement of the sides **116**, **118** away from each other when the frame **110** is under compression. In other examples, the support bar **150** may be slightly above or below the neutral axis **132**, such that the wires **130** can be disposed in the neutral axis **132**. In examples, the number of support bars **150** and/or other support members may be minimized, to reduce an impact on throughput of the screening panel **100**, as noted above. Fewer support bars results in the screening panel **100** being a better self-cleaning device with greater throughput since the present invention's use of pre-tensioned wires minimizes the spacing between the wires from expanding such that the screens have an increased efficiency of self-cleaning properties.

(40) When the tensioned wires **130** (the tension force is illustrated by arrows **204** and range from 2,000 to 5,000 lbs.) are positioned in or as close to the neutral axis **132** as possible, then the tensioned wire **130** can be attached to the frame **110** when the frame **110** is being or already compressed (the compression force is illustrated by arrows **200** and range from 1,000 lbs. to 3,000 lbs.) during the manufacturing process. The screening panel **100** experiences (a) compression forces on the frame **110** and (b) the tension forces when the tensioned wires are securely attached to the frame **110** at or near the same time, then the screening panel **100** should experience lower bending forces (arrows **202**). That in turn, should render the screening panel **100** a more stable product that retains the desired wire tension that results in superior self-cleaning characteristics and greater throughput capabilities.

(41) As can be readily appreciated, the wires **130** are tensioned in one direction (see arrows **204**) when positioned and attached to the frame—between the first attachment frame end **112** and the second attachment frame end **114**—and in the neutral axis **132**. It is also understood that the wires **130** can have different tensions. For example, the wires **130** positioned or to be positioned at or near the center of (A) the screen spacing area **120** and (B) the first attachment frame end **112**, the second attachment frame end **114** can be at a higher tension (1 to 50% greater, 5 to 25% greater and/or 10 to 20% greater) than the wires **130** positioned or to be positioned at or near the first frame side **116** and the second frame side **118** and/or any support member parallel to the frame sides. That various tensioned wire embodiment, combined with the optional compressed frame **110**, provides for more consistent tensioning of all wires in the screening area. For example, along the attachment frame ends **112**, **114**, the frame is more rigid proximate the sides **116**, **118**, than at positions nearer the centers of frame ends **112**, **114** (spaced from the sides **116**, **118**). Because of this varied rigidity, the frame may provide different resistances to the tensioned wires, and in this example the wires are tensioned based on these different resistances, with the result being more evenly tensioned wires. Differently tensioning the wires may result in a more efficient self-cleaning screen apparatus.

(42) It is also understood that some of the wires **130** positioned adjacent to or very near the first frame side **116** and/or the second frame side **118** could be un-tensioned while the remaining wires **130** positioned along and near the screen spacing area's **120** center line **125** that extends from the first attachment frame end **112** to the second attachment frame end are tensioned. The more efficient self-cleaning screen apparatus is maintained with the present invention on the condition that the un-tensioned wires **130** positioned adjacent to or very near the first frame side **116** and/or the second frame side **118** have a tension strength after the frame is decompressed that is the same

or equivalent (within 1 to 25%) of the tension of the tensioned wires **130** positioned along and near the screen spacing area's **120** center line **125**, when the frame is decompressed.

(43) That one directional wire tensioning also permits the wires **130** while in the screening panel **100** to provide (i) a more efficient self-cleaning screen apparatus and (ii) greater precision in the throughput when the screening panel **100** is installed in the screening machine. Moreover, when the screening panel **100** is installed in the screening machine, the screening panel **100** with the tensioned wires **130** is not subject to further tensioning of the frame **110** and/or wires **130** since the screening panel **100** with the tensioned wires **130** is properly sized to easily be installed into the screening machine without applying further tension to the screening panel **100** when being installed. It is understood that the screening panel **100** may be further tensioned in some screening machines during installation or operation, however that is unlikely since the present invention's modular, self-cleaning screens is designed to be placed in a receptacle for vibratory screening machine. But for the most part, the screening panel **100** need not be further tensioned with most vibratory screening machines.

(44) In contrast, when un-tensioned screening panels are installed into screening machines, the un-tensioned screening panels must be adjusted, in many instances by numerous employees, into the screening machine to properly be installed therein and obtain the desired tension in the wires and frame. Such endeavors are undesirable, and objectives can be difficult or unpredictable to achieve.

(45) Making one version of the tensioned screening panel is accomplished by a multi-step process using a dual carriage device **300**. The dual carriage device **300** has a frame compressing unit **310** and a screen tensioning unit **330**, as illustrated at FIG. 5.

(46) The frame compressing unit **310** has a first securing unit **312** that releasably secures the first attachment frame end **112** in the proper position during the assembly process of the screening panel **100**; and a second securing unit **314** that releasably secures the second attachment frame end **114** in the proper position during the assembly process of the screening panel **100**. The first securing unit **312** and the second securing unit **314** can releasably secure the respective first and second attachment frame ends **112**, **114** through clamps, screws, nuts and bolts, or combinations thereof; or alternatively the first securing unit **312** and the second securing unit **314** merely contact and push the respective first and second attachment frame ends **112**, **114** toward each other.

(47) In one embodiment illustrated at FIG. 5, the second securing unit **314** is stationary while the first securing unit **312** is on a carriage **313**. The carriage **313** moves on rails **319** in directions—identified by arrows **318**—parallel to the first frame side and the second frame side when the frame **110** is releasably secured (or contacted and pushed) in the first and second securing units **312**, **314**. The first securing unit **312** on the carriage **313** and interconnected to a hydraulic system (or servomotors, linear actuators or other types of actuators) **316** moves toward the lower securing unit **314** and can compress (arrows **200**) the frame **110** a predetermined distance. The hydraulic system **316** can be hydraulic fluid contained in conventional pistons in order to control the movement of the upper securing unit **312**; or alternatively, the hydraulic system **316** could be replaced with any other system that accomplishes the same objectives as the hydraulic system **316**. For example, the relative movement could be accomplished using a manually-operated system, a system driven by servo motors, linear actuators, pneumatics, or the like. The upper securing unit **312** in conjunction with the hydraulic system **316**—after an operator (a) positions the frame **110** within the upper securing unit **312** and the lower securing unit **314** and (b) initiates the hydraulic system **316**—compresses the first attachment frame end **112** toward the second attachment frame end **114** a predetermined distance. The predetermined distance can range from 0.01 mm to 2 mm. In the alternative way, at least one block contacts the attachment frame end **112** and at least one pusher contacts the second attachment frame end **114** (or vice versa or there are at least one pusher on each frame end **112**, **114**). The at least one pusher moves and causes each frame end **112**, **114** to bow under the compressive force resulting from the movement. At which point, the pre-tensioned wires are attached to the bowed frame and the bowing resists the tension. The displacement of the frame

ends **112**, **114** will vary across the width as a result of the bowing, with the understanding that in the middle of the frame ends **112**, **114** the distance will be greater and at the sides of the frame ends **112**, **114** the distance will be less.

(48) Alternatively, the lower securing unit **314** can be on the carriage **313** and interconnected to the hydraulic system **316**, and the upper securing unit **312** is stationary. The hydraulic system **316** can be hydraulic fluid contained in conventional pistons in order to control the movement of the lower securing unit **314**; or alternatively, the hydraulic system could be replaced with any other system that accomplishes the same objectives as the hydraulic system **316**. For example, the relative movement could be accomplished using a manually-operated system, a system driven by servo motors, linear actuators, pneumatics, or the like. The lower securing unit **314** in conjunction with the hydraulic system **316**—after an operator (a) positions the frame **110** within the upper securing unit **312** and the lower securing unit **314** and (b) initiates the hydraulic system **316**—compresses the second attachment frame end **114** toward the first attachment frame end **112** a predetermined distance.

(49) Alternatively, the lower securing unit **314** and the upper securing unit **312** are respectively on their own carriages **313** and interconnected to the hydraulic system **316**. The hydraulic system **316** can be hydraulic fluid contained in conventional pistons in order to control the movement of the upper and lower securing units **312**, **314**; or alternatively, the hydraulic system **316** could be replaced with any other system that accomplishes the same objectives as the hydraulic system **316**. For example, the relative movement could be accomplished using a manually-operated system, a system driven by servo motors, linear actuators, pneumatics, or the like. The upper and lower securing units **312**, **314** in conjunction with the hydraulic system **316**—after an operator (a) positions the frame **110** within the upper securing unit **312** and the lower securing unit **314** and (b) initiates the hydraulic system **316**—compresses the second attachment frame end **114** and the first attachment frame end **112** toward each other a predetermined distance.

(50) Either prior to or after the frame **110** is compressed, the operator applies the adhesive **198** on the lower bonding surface **124**. The adhesive **198** is sufficiently applied so that when the wire **130** is properly positioned on the frame **110**, the portion of the wire **130** that is supposed to contact the adhesive **198** is also encapsulated by the adhesive **198** as illustrated at FIGS. **8A** and **8B**. By encapsulated, the wire's top surface, bottom surface and both side surfaces are in the adhesive **198**. That way, there is no bond area starvation below, above or on the sides of the portion of the wire **130** that is supposed to contact the adhesive **198**. The wire **130** can (a) have a slight bend as it is positioned over the upper bond area **122**, and the lower bonding surface **124** as illustrated at FIG. **8A** or (b) conform to the shape of the upper bond area **122** and the lower bonding surface **124** as illustrated at FIG. **8B**.

(51) Either prior to or after the frame **110** is compressed, the wires **130**—having any of the above-identified configurations or combinations thereof—are releasably secured to the screen tensioning unit **330**. Like the frame carriage compressing unit **310**, the screen tensioning unit **330** has a first tensioning unit **332** that releasably secures a first location of the wires **130** in a proper position during the assembly process of the screening panel **100**; and a second tensioning unit **334** that releasably secures a second location of the wires (usually the first location is one end of the wire to be tensioned and the second location is the opposite end of the wire to be tensioned) in the proper position during the assembly process of the screening panel **100**.

(52) In one embodiment, the upper tensioning unit **332** is stationary while the lower tensioning unit **334** is on a carriage system **335**. The carriage **335** moves on rails **339** in directions—identified by arrows **338**—parallel to (a) the first frame side and the second frame side when the frame **110** is releasably secured in the first and second securing units **312**, **314**, and (b) the wires **130** when the wires **130** are releasably secured in the first and second tensioning units **332**, **334**. The second tensioning unit **334** on the carriage **335** and interconnected to a second hydraulic system **336** moves away from the first tensioning unit **334** and to provide tension (arrows **204**) to the wires **130** by

moving a predetermined distance.

(53) The second hydraulic system **336** (i) operates in the same way as hydraulic system **316** and (ii) could be the same system as the hydraulic system **316**. After (a) the wires are properly positioned in the first and second tensioning units **332**, **334**; (b) the wires need to be tensioned, and (c) the operator initiates the second hydraulic system **336**—the second tensioning unit **334** moves away from the first tensioning unit **332** a predetermined distance to obtain the desired tension for the screening panel **100**.

(54) Alternatively, the second tensioning unit **334** is stationary while the first tensioning unit **332** is on a carriage system—interconnected to a second hydraulic system **336**—that moves—after (a) the wires are properly positioned in the first and second tensioning units **332**, **334**; (b) the wires need to be tensioned, and (c) the operator initiates the second hydraulic system **336**—the first tensioning unit **332** away from the second tensioning unit **334** a predetermined distance to obtain the desired tension for the screening panel **100**.

(55) Alternatively, the first tensioning unit **332** is on an first carriage system and the second tensioning unit **334** is on a second carriage system, wherein the first carriage system and the second carriage system are interconnected to the second hydraulic system **336** that moves—after (a) the wires are properly positioned in the first and second tensioning units **332**, **334**; (b) the wires need to be tensioned, and (c) the operator initiates the second hydraulic system **336**—the second tensioning unit **334** and the first tensioning unit **332** away from each other a predetermined distance to obtain the desired tension for the screening panel **100**.

(56) Once (a) the wires **130** are tensioned, (b) the frame **110** is compressed, and (c) the adhesive **198** is applied to the frame **110**, the frame carriage compressing unit **310** is moved (see, arrows **360**) toward the screen tensioning unit **330** so the frame **110** and the adhesive **198** contacts the wires **130** located between the second tensioning unit **334** and the first tensioning unit **332**. The wires are then securely attached after the adhesive is cured to the frame **110** and the wires. That movement **360** can be accomplished by conventional hydraulic motions using, for example, the hydraulic system **316**.

(57) Alternatively, when the frame **110** is compressed and the tensioned wires **130** contact the second attachment frame end **114** and the first attachment frame end **112**, an operator can weld the tensioned wires **130** that contact the frame **110** to the second attachment frame end **114** and the first attachment frame end **112**.

(58) Once the tensioned wires **130** are fastened or secured to the optionally compressed frame **110**, the screen tensioning unit **330** is adjusted so if there are portions of the wires not positioned in the screen spacing **120** and attached to the frame **110** become un-tensioned. The un-tensioned wires can then be safely cut or removed so the compressed frame **110** and tension wires **130** can be removed from the dual carriage device **300**.

(59) In the example just described, the wires are put in tension and the frame is compressed prior to wires being fixed to the frame. Forces in the compressed frame counter forces in the tensioned wires to maintain the wires in tension when the connected wires and frame are removed from the dual carriage device. Although the example just discussed achieves this tension through both the tensioning of the wires with the screen tensioning unit and the compression of the frame using the frame compressing unit, other example methods may include only tensioning wires with the screen tensioning unit. In some examples, the frame may have sufficient rigidity to resist the tension of the wires without the need to first compress the frame. In another example, untensioned wires may be secured to a frame maintained in compression, for example, by the frame compression unit. When the compression is released, the frame may apply a force to wires sufficient to place the wires in tension.

(60) Other variations to the described method also may be used. For example, although the screen tensioning unit is illustrated as clamping all wires and tensioning them uniformly, in other examples the screen tensioning unit can tension wires independently or in groups, similar to the

example discussed above. For example, wires closer to the frame sides may require less tension (because the sides provide additional frame rigidity) whereas wires closer to the center of the attachment frame ends may be subjected to a higher tension (because they are farther from the sides and therefore the frame has less rigidity). In addition to the benefits discussed above, this selective tensioning may be particularly useful in methods that do not include pre-compression of frame, because the frame will resist the tensioning differently at different area. Other methods and/or modifications also are contemplated.

(61) Regardless of the method used, we have demonstrated a modular screening panel having a fixed size and/or shape with tensioned wires. The use of wires allows for the screen to be self-cleaning, thereby providing improvements over mesh screens. Moreover, by tensioning the wires at manufacture or fabrication, screens disclosed herein provide improvements over panel screens that require tensioning at installation. Furthermore, tensioning the wires at manufacture provides an improved screen over modular screens that do not have tensioned wires. Without limit, because previous modular screens did not have tensioned wires, they were usually fabricated from wires having some minimal rigidity (generally thicker wires) to prevent sagging or excessive movement during vibration. Alternatively, previous modular screens without tensioned wires needed several supports for the wires, to prevent this sagging and excessive movement, which reduced overall throughput of the screen.

(62) It may be possible to add one or more additional wires to the wires **130** in the screen spacing area **120**. For instance, these additional wires may not be parallel with the tensioned wires **130**. The wires may be used for support, e.g. as with the support member **150**, or for other purposes. The disclosure is not limited to only wires, like the wires **130**, extending generally in a single direction. However, examples of this disclosure may differentiate over mesh patterns that require interwoven wires in different directions that may prohibit the self-cleaning of the screen, as described herein.

(63) FIG. **9** is an examples flow chart showing an example process **900** for manufacturing a screen panel, such as the panel **100**.

(64) At an operation **980**, the process **900** includes tensioning a plurality of wires and/or compressing a frame. These operations are detailed above. For example, tensioning the plurality of wires may include gripping, clamping or otherwise securing the wires proximate a first end by a first unit and proximate an opposite, second end by a second unit, and moving the units relative to each other, e.g., away from each other, to place the wires in tension. Compressing the frame may include placing the ends of a frame between movable units and moving the units relative to each other, e.g., closer to each other, to compress the frame. For instance, the compression may cause portions of the ends of the frame to bow or displace so as to be relatively closer to each other.

(65) At an operation **982**, the process **900** includes securing the wires to the frame. As discussed above, with the wires in tension and/or the frame in compression, the wires are welded, adhered or otherwise secured to the frame ends.

(66) At an operation **984**, the process **900** includes releasing the tension and/or compression. In some examples, a machine, such as the dual carriage machine discussed above may be used to place the wires in tension and/or the frame in compression. Upon securing the wires to the frame, e.g., after a curing time for adhesive, cooling of welds or the like, the machine may remove the tension and/or compression. Once released, the frame and the wires reach an equilibrium in which the wires remain (or are placed) in tension and the frame remains (or is placed in) compression. The result is a screening panel **120** with tensioned wires, as in FIG. **2**.

(67) In some examples, the process **900** may include additional steps. For instance, the process **900** can include additional steps to modify the panel **120** for use in different machines.

(68) At an operation **986**, the process **900** can optionally include masking the wires. For example, a mask may be applied to the tensioned wires **130** that are to be exposed when the screening panel is in use. For instance, the portions of the tensioned wires **130** that are arranged in the panel spacing **320** may be masked.

(69) At an operation **988**, the process **900** can also optionally include applying additional structure to the unmasked areas of the screen **320**. For instance, the additional structure may comprise the interconnecting exterior structure **352**. In some examples, the additional structure can be a polymeric structure, such as urethane, rubber, or the like. The additional structure may be designed so the screening panel **100** can be removably and securely positioned in a desired vibratory machine.

(70) The operation **988** may include applying the additional structure using a molding process, such as molding or injection molding. In some examples, a die or mold includes a cavity sized to receive portions of the screening panel **120** with tensioned wires. For instance, the die or mold can include a cavity that receives the frame **110** and provides additional spacing around the frame **110**. Mold material, e.g., liquid polymer, is introduced into the cavity. Upon curing, the mold material encapsulates the frame **110**, e.g., on all sides, as well as the attachment of the wires **130** to the frame **110**. When the die is removed, the result may be the modular screen **100** with interconnecting structure **352**, shown in FIG. 4. As also illustrated in FIG. 4, the mold material can also encapsulate the support bar **150** and portions of the wires **130** proximate the support bar **150**. While not shown specifically in FIG. 4, the mold material may further contact (and/or encapsulate) additional portions of the wires **130**. Without limitation, portions of the wires **130** closest to the sides **112**, **114** may be at least partially encapsulated by the mold material.

(71) In at least some examples, the mold or die used to create the panel **100** of FIG. 4 may be sized to receive the entire frame **110**. For example, the frame **110** with tensioned wires **130** may be placed in a die that includes cavities to create all of the exterior interconnecting structure **352**, e.g., in a single mold step. In some examples, the mold or die may include a masking region that receives portions of the wires **130** that are not to be overmolded. Without limitation, the masking region can include a soft polymer that is configured to receive and contact portions of the wires **130** in one or more of the configurations discussed above. Applying the exterior structure **352** in a single step mold processing obviates the need for one or more additional fabrication steps. For instance, some conventional modular screens mold their frames prior to attachment of their untensioned wires. In some instances, ends of these untensioned wires may also be molded. The wires are then fastened to the screens.

(72) Although the operation **988** is described in connection with applying a polymeric or molded material as the additional structure, other additional structures are contemplated. The additional structures may vary based on the vibratory machine with which the modular screen **100** is to be used. For instance, the additional structure can include mounting structures such as flanges, tabs, detents, fasteners, or the like. In other examples, this additional structure may be initially included in the frame **110**. The additional structure can also include gaskets, spacers, seals and/or the like. As noted, the additional materials may be added to facilitate use of our screen with tensioned wires with different types of vibratory machines. As will be appreciated, with the operation **986** does not require applying a mold as the additional structure, the process **900** may omit masking the wires at the operation **986**.

(73) Thus, it is seen that the objects of the present invention are efficiently obtained, although modifications and changes to the invention should be readily apparent to those having ordinary skill in the art, which modifications are intended to be within the spirit and scope of the invention as claimed. It also is understood that the foregoing description is illustrative of the present invention and should not be considered as limiting. Therefore, other embodiments of the present invention are possible without departing from the spirit and scope of the present invention.

Claims

1. A screening panel comprising: a frame defining a fixed screen spacing area and comprising a first frame end spaced from a second frame end in a longitudinal direction; and a plurality of wires

arranged parallel to each other on the frame and disposed at least partially in the fixed screen spacing area, individual of the plurality of wires being fixed proximate a first wire end to the first frame end and being fixed proximate a second wire end to the second frame end, the plurality of wires being pre-tensioned between the first wire end and the second wire end.

2. The screening panel of claim 1, wherein the plurality of wires are in tension such that, when a wire of the plurality of wires cut at a longitudinal position between the first wire end and the second wire end, at least one of a first portion of the wire between the first wire end and the cut shortens in the longitudinal direction or a second portion of the wire between the second wire end and the cut shortens in the longitudinal direction.

3. The screening panel of claim 1, wherein at least one of the first frame end or the second frame end further comprises a bonding surface and a raised bonding surface.

4. The screening panel of claim 3, wherein the plurality of wires contact the raised bonding surface and are secured to the bonding surface using an adhesive, the raised bonding surface inhibiting migration of the adhesive.

5. The screening panel of claim 1, wherein the plurality of wires are pre-tensioned from about 2,000 lbs. to about 5000 lbs.

6. The screening panel of claim 1, further comprising a polymeric structure encapsulating at least a portion of the frame and ends of the plurality of wires, the polymeric structure having at least one of a size or a shape to facilitate coupling of the screening panel to a vibratory machine.

7. The screening panel of claim 6, wherein the polymeric structure at least partially encapsulates at least one of a first wire of the plurality of wires proximate the first frame side or a second wire of the plurality of wires proximate the second frame side.

8. The screening panel of claim 1, wherein: the frame further comprises at least one support extending laterally between a first frame side and a second frame side, at a position spaced from the first frame end and the second frame end; and the plurality of wires are disposed to contact the support.

9. The screening panel of claim 1, wherein: the first frame end has a first neutral axis extending generally along a longitudinal axis of the first frame end; the second frame end has a second neutral axis extending generally along a longitudinal axis of the second frame end; and the plurality of wires are arranged proximate a plane coincident with the first neutral axis and the second neutral axis.

10. A method of forming a screening panel comprising: providing a plurality of wires, the plurality of wires extending generally from first wire ends to second wire ends in a longitudinal direction; providing a frame comprising a first frame end spaced from a second frame end in the longitudinal direction and a first frame side spaced from a second frame side in a lateral direction; with the plurality of wires separate from the frame, tensioning the plurality of wires in the longitudinal direction; with the at least one of the plurality of wires tensioned in the longitudinal direction, securing the first wire ends of the plurality of wires to the first frame end and securing the second wire ends of the plurality of wires to the second frame end; and releasing the tensioning with the wires secured to the frame to provide a screening panel with pre-tensioned wires.

11. The method of claim 10, wherein the tensioning the un-tensioned wires comprising: securing, via a first unit, the plurality of wires proximate the first wire ends; securing, via a second unit, the plurality of wires proximate the second wire ends; and moving the first unit relative to the second unit to place the plurality of wires in tension.

12. The method of claim 11, wherein the moving the first unit relative to the second unit imparts a force of from about 2000 pounds to about 5000 pounds of tension on the plurality of wires.

13. The method of claim 10, wherein the at least one of the tensioning the un-tensioned wires or the compressing the frame comprises tensioning the un-tensioned wires, the tensioning the un-tensioned wires comprising: tensioning a first wire of the plurality of wires to a first tension; and tensioning a second wire of the plurality of wires to a second tension.

14. The method of claim 13, wherein a longitudinal axis bisects the frame between the first frame side and the second frame side, the first wire is disposed relatively closer to the longitudinal axis than the second wire, and the first tension is greater than the second tension.

15. The method of claim 10, wherein at least one of the securing the first wire ends to the first frame end or the securing the second wire ends to the second frame end comprises at least one of adhering or welding.

16. The method of claim 10, further comprising: applying an overmold to the screening panel with tensioned wires.

17. The method of claim 16, wherein the overmold encapsulates at least a portion of the first frame end, the second frame end, the first frame side, the second frame side, the first wire ends and the second wire ends.

18. The method of claim 16, wherein the overmold further encapsulates at least a portion of the at least one of a first wire of the plurality of wires proximate the first frame side or a second wire of the plurality of wires proximate the second frame side.

19. The screening panel of claim 1, wherein the screening panel has a fixed size and shape for coupling to the vibratory machine.

20. The screening panel of claim 19, further comprising an interconnecting structure disposed over the frame and at least a portion of the plurality of pre-tensioned wires, the interconnecting structure providing the screening panel with the fixed size and shape.
