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Coupling Having Visual Installation Indicators

Abstract

A pipe coupling has two segments with action surfaces in facing relationship. Attachment elements on each segment, in the form of lugs, accommodate adjustable fasteners which draw the segments together when tightened. Support surfaces on the lugs engage one another to visually indicate that a proper installation of the coupling has been achieved.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] This application is a Continuation of U.S. application Ser. No. 17/736,124, filed May 4, 2022, which is a Continuation-in-Part of U.S. application Ser. No. 17/510,865, filed Oct. 26, 2021, which application is based upon and claims benefit of priority to U.S. Provisional Application No. 63/110,433, filed Nov. 6, 2020, all applications being hereby incorporated by reference herein.

FIELD OF THE INVENTION
[0002] This invention relates to mechanical couplings for joining pipe elements.
BACKGROUND
[0003] Prior art segmented mechanical couplings which rely on contact between the coupling and the pipe elements which they join in order to create a sufficiently stiff, or rigid joint may present challenges during installation, for example, in ease of assembly and the lack of consistent and identical visual indication that a coupling is properly installed in all intended conditions and over all pipe element tolerance ranges. Because such couplings rely on contact between the between the coupling and the pipe elements, they are affected by the wide tolerance ranges of the pipe surface as well as the tolerance range on the interfacing surface of the coupling. In couplings which rely on forceful radial contact between the pipe elements and the interfacing surfaces on the couplings, this dependency often results in varying gaps between the connection members which are used to hold the segments one to another around the pipe. While these gaps may not affect coupling performance, they complicate assembly by preventing the use of contact between the interfacing surfaces of the connection members as a reliable visual indicator of complete and proper assembly. Other forms of segmented couplings, especially those used on grooved pipe elements, have addressed this challenge in the art by having the engagement of the connection members occur along an inclined plane, such that rotation of the segments is induced, causing the segments to rotate relatively to one another such that the “keys” of the coupling lock into the circumferential grooves of the pipe elements and form a sufficiently stiff, or rigid joint in bending and torsion between them. U.S. Pat. No. 4,639,020 to Rung et al., hereby incorporated by reference herein, discloses an example of such a coupling. However, the more complicated interface between the coupling segments creates additional cost and adds complexity due to the rotation of the coupling segments relative one to another. There is clearly an opportunity to improve segmented mechanical couplings so they are easier to assemble and provide consistent and unambiguous visual indication confirming proper installation.
SUMMARY
[0004] The invention concerns a coupling for joining pipe elements in end to end relation. In an example embodiment, a coupling according to the invention comprises first and second segments attached to one another end to end surrounding a central space for receiving the pipe elements. Each segment comprises a first lug extending from a first end thereof and a second lug extending from a second end thereof. The first and second lugs of the first segment align respectively with the first and second lugs of the second segment. A first adjustable fastener extends between the first lugs and a second adjustable fastener extends between the second lugs. In an example embodiment each segment further comprises a first action surface positioned between the central space and the first lug, and a first support surface positioned on the first lug. The first fastener is positioned between the first action surface and the first support surface, the first action surface and the first support surface are oriented transversely to a longitudinal axis of the first fastener. A second action

surface is positioned between the central space and the second lug, and a second support surface is positioned on the second lug. The second fastener is positioned between the second action surface and the second support surface, the second action surface and the second support surface are oriented transversely to a longitudinal axis of the second fastener.

[0005] In an example embodiment, the first lugs may be adapted, upon tightening of the first adjustable fastener, to assume either a first configuration, wherein the first action surfaces are in contact with one another and the first support surfaces are in contact with one another, or a second configuration, wherein the first support surfaces are in contact with one another, there being a gap between the first action surfaces. Further by way of example, the second lugs may be adapted, upon tightening of the second adjustable fastener, to assume either a first configuration, wherein the second action surfaces are in contact with one another and the second support surfaces are in contact with one another, or a second configuration, wherein the second support surfaces are in contact with one another, there being a gap between the second action surfaces.

[0006] In an example embodiment the first lugs define a first opening surrounding a first axis oriented transversely to the longitudinal axis of the first fastener and positioned between the first action surfaces and the first support surfaces. In a particular example the first opening extends through the first lugs. In further example the second lugs define a second opening surrounding a second axis oriented transversely to the longitudinal axis of the second fastener and positioned between the second action surfaces and the second support surfaces. The second opening may extend through the second lugs by way of example.

[0007] In an example embodiment each one of the first and second adjustable fasteners comprises a nut and bolt. In a further example, each of the segments comprises first and second arcuate projections positioned on opposite sides of the segments. Each of the arcuate projections faces the central space, and each of the arcuate projections is engageable within circumferential grooves in the pipe elements when the segments are drawn toward one another by the adjustable fasteners. By way of example a seal may be positioned within the central space. The seal supports the segments in spaced apart relation sufficient to permit insertion of the pipe elements into the central space without disassembling the coupling.

[0008] The invention further encompasses a coupling for joining pipe elements in end to end relation wherein the coupling comprises first and second segments attached to one another end to end surrounding a central space for receiving the pipe elements. Each segment comprises a first lug extending from a first end thereof. The first lug of the first segment aligns with the first lug of the second segment. A first adjustable fastener extends between the first lugs. In this example embodiment each segment further comprises a second end. The second ends of the segments are arranged opposite to the first ends respectively, and each second end is connected to a hinge joining the first and second segments to one another. The hinge defines a hinge axis oriented transversely to a longitudinal axis of the first fastener. The first and second segments are pivotable about the hinge axis. In this example each segment further comprises a first action surface positioned between the central space and the first lug, and a first support surface positioned on the first lug. The first fastener is positioned between the first action surface and the first support surface. The first action surface and the first support surface are oriented transversely to the longitudinal axis of the first fastener.

[0009] In an example embodiment the first lugs may be adapted, upon tightening of the first adjustable fastener, to assume either a first configuration, wherein the first action surfaces are in contact with one another and the first support surfaces are in contact with one another, or a second configuration, wherein the first support surfaces are in contact with one another, there being a gap between the first action surfaces. Further by way of example, the first lugs define a first opening surrounding a first axis oriented transversely to the longitudinal axis of the first fastener and positioned between the first action surfaces and the first support surfaces. In a specific example, the first opening extends through the first lugs. Further by way of example the first adjustable fastener

comprises a nut and bolt.
[0010] In an example coupling according to the invention, each of the segments comprises first and second arcuate projections positioned on opposite sides of the segments. Each of the arcuate projections face the central space. Each of the arcuate projections is engageable within circumferential grooves in the pipe elements when the segments are drawn toward one another by the adjustable fastener. An example embodiment may further comprise a seal positioned within the central space. The seal supports the segments in spaced apart relation sufficient to permit insertion of the pipe elements into the central space without disassembling the coupling.
[0011] In a further example the first support surface of at least one of the segments may be offset from the first action surface of the at least one segment, the offset being measured from the first action surface. Also by way of example, the second support surface of the at least one segment may be offset from the second action surface of the at least one segment, the offset of the second support surface being measured from the second action surface. In another example the first support surface of at least one of the segments may be oriented at a first orientation angle measured with respect to a plane extending between the first and second segments. Also by way of example, the first action surface of the at least one segment may be oriented at a second orientation angle measured with respect to the plane. In an example embodiment, the first orientation angle may be equal to the second orientation angle.
[0012] In an example embodiment the first action surface and the first support surface of the first segment may be oriented at a first orientation angle measured with respect to a plane extending between the first and second segments. The first action surface and the first support surface of the second segment may oriented at a second orientation angle measured with respect to the plane. The second action surface and the second support surface of the first segment may be oriented at a third orientation angle measured with respect to the plane. The second action surface and the second support surface of the second segment may be oriented at a fourth orientation angle measured with respect to the plane in another example. Further by way of example, the support surface of at least one of the segments may be offset from the action surface of the at least one segment with the offset being measured from the action surface.
[0013] In another example embodiment the action surface and the support surface on the first segment may be oriented parallel to a first ray extending from a fulcrum of the hinge, and the action surface and the support surface on the second segment may be oriented parallel to a second ray extending from the fulcrum of the hinge. Further by way of example, the action surface on the first segment may be oriented parallel to a first ray extending from a fulcrum of the hinge, the support surface on the first segment may be oriented parallel to a second ray extending from the fulcrum of the hinge, the action surface on the second segment may be oriented parallel to a third ray extending from the fulcrum of the hinge and the support surface on the second segment may be oriented parallel to a fourth ray extending from the fulcrum of the hinge. In an example embodiment the second and the fourth rays may subtend a first angle larger than a second angle subtended by the first and third rays or a first angle smaller than a second angle subtended by the first and third rays.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0014] FIG. **1** is an isometric view of an example mechanical coupling according to the invention shown in a factory assembled state;
[0015] FIG. **2** is an end view of the coupling shown in FIG. **1**;
[0016] FIGS. **3** and **4** show end views of the example coupling during installation;
[0017] FIG. **5** is an isometric view of another example mechanical coupling according to the

invention shown in a factory assembled state;
[0018] FIG. **6** is an end view of the coupling shown in FIG. **5**;
[0019] FIGS. **7** and **8** show end views of the example coupling during installation;
[0020] FIG. **9** is a front view of another example embodiment of a coupling according to the invention;
[0021] FIG. **10** is an isometric view of another example embodiment of a coupling according to the invention in a factory assembled state;
[0022] FIG. **10**A is a partial section view through an example coupling as shown in FIG. **10** in a fully installed state;
[0023] FIG. **11** is a front view of the example coupling shown in FIG. **10**;
[0024] FIGS. **11**A-**11**F are front views of portions of the coupling shown in FIG. **11** on an enlarged scale;
[0025] FIGS. **12** and **13** are front views showing the example coupling of FIG. **10** in use on a pipe element having a circumferential groove with a diameter near the lower end of the tolerance range;
[0026] FIGS. **14** and **15** are front views showing the example coupling of FIG. **10** in use on a pipe element having a circumferential groove with a diameter near the higher end of the tolerance range;
[0027] FIGS. **16** and **16**A are front views of example hinged pipe couplings according to the invention;
[0028] FIG. **16**B is a front view of portions of the coupling shown in FIG. **16**A; and
[0029] FIGS. **17** and **18** are partial section views of example couplings according to the invention as employed with plain end pipe elements.
DETAILED DESCRIPTION
[0030] FIG. **1** shows an example coupling **10** according to the invention for joining pipe elements (not shown) in end to end relation. In this example the coupling **10** comprises a first segment **12** and a second segment **14**. Segments **12** and **14** are attached to one another end to end to surround and define a central space **16** for receiving the pipe elements. Coupling **10** is designed to join pipe elements having circumferential grooves at an end and thus each of the segments **12** and **14** comprises first and second arcuate projections **18***a* and **18***b* (see also FIG. **2**), also known as "keys", positioned on opposite sides **20** and **22** of the segments **12** and **14**. The arcuate projections **18***a* and **18***b* face the central space **16** and are engageable within circumferential grooves in the pipe elements when the segments are drawn toward one another to form a joint. A seal **24** is positioned within the central space **16**. Seal **24** is advantageously a ring gasket made of an elastomer such as EPDM, and may support the segments **12** and **14** in spaced apart relation as shown, at a distance sufficient to permit insertion of the pipe elements into the central space **16** without disassembling the coupling **10**. Couplings according to the invention may also be used with plain end pipe, shouldered pipe or other formed pipe ends known in the art.
[0031] As further shown in FIG. **1**, each segment **12**, **14** comprises a first lug **26** extending from first ends **28** thereof. A second lug **30** extends from a second end **32** of each segment. The first and second lugs **26** and **30** of the first segment **12** align respectively with the first and second lugs **26** and **30** of the second segment **14**. A first adjustable fastener **34** extends between the first lugs **26** of each segment **12** and **14**, and a second adjustable fastener **36** extends between the second lugs **30** of each segment. In this example the first and second adjustable fasteners **34** and **36** comprise a nut **38** and bolt **40**.
[0032] Each segment **12** and **14** further comprises a first action surface **42** positioned between the central space **16** and the first lug **26**. A first support surface **44** is positioned on the first lug **26** of each segment **12** and **14**. The first fastener **34** is positioned between the first action surfaces **42** and the first support surfaces **44** of the segments **12** and **14**. As shown in FIGS. **1** and **2**, the first action surfaces **42** and the first support surfaces **44** are oriented at a first angle **46** transverse to a longitudinal axis **48** of the first fastener **34**. The first angle **46** may have a slope ranging from 45° to 70°, with a slope of 60° considered advantageous. As shown in FIG. **1**, a second action surface **50**

is positioned between the central space **16** and the second lug **30** on each segment **12** and **14**. A second support surface **52** is positioned on the second lugs **30** of each of the segments **12** and **14**. The second fastener **36** is positioned between the second action surfaces **50** and the second support surfaces **52** of the segments **12** and **14**. The second action surfaces **50** and the second support surfaces **52** are oriented at a second angle **54** transverse to a longitudinal axis **56** of the second fastener **36**. The second angles **54** of the second action surfaces **50** and the second support surfaces **52** have an opposite slope from the first angle **46** of the first action surfaces **42** and the first support surfaces **44**. It is advantageous if the slopes of the first and second angles **46** and **54** are also equal in magnitude as well as opposite in sign. Although, in the embodiments disclosed in this specification, the first and second action surfaces **42** and **50** have the same angular orientations as the first and second support surfaces **44** and **52** respectively, a practical design may also advantageously have action surfaces with orientation angles which differ from the orientation angles of their adjacent associated support surfaces.

[0033] At least a first stop surface **58** is positioned on the first lugs **26** of each segment **12** and **14** adjacent to the first support surfaces **44**. The first stop surfaces **58** are oriented at a third angle **60** (see FIG. **1**) having a slope opposite to the slope of the first angle **46**. At least a second stop surface **62** is positioned on the second lugs **30** of each segment **12**, **14** adjacent to the second support surfaces **52**. The second stop surfaces **62** are oriented at a fourth angle **64** having a slope opposite to the second angle **54**.

[0034] Advantageously, the first lugs **26** may define a first opening **27** surrounding a first axis **29** oriented transversely to the longitudinal axis **48** of the first fastener **34** and positioned between the first action surfaces **42** and the first support surfaces **44**. In a practical embodiment, the first opening **27** extends through the first lugs **26**. The bending stiffness of the first lugs **26** may be tuned to a desired value by properly sizing the first opening **27**. Similarly, the second lugs **30** may define a second opening **31** surrounding a second axis **33** oriented transversely to the longitudinal axis **56** of the second fastener **36** and positioned between the second action surfaces **50** and the second support surfaces **52**. In a practical embodiment, the second opening **31** extends through the second lugs **30**. The bending stiffness of the second lugs **30** may be tuned to a desired value by properly sizing the second opening **31**.

[0035] Operation of coupling **10** is described with reference to FIGS. **1-4**. FIGS. **1** and **2** show the example coupling **10** in the factory assembled configuration with segments **12** and **14** supported in spaced apart relation on seal **24** at a distance from one another sufficient to permit pipe elements (not shown) to be inserted into the central space **16**. In this factory assembled example fasteners **34** and **36** have been tightened sufficiently to hold the segments against the seal. The pipe elements are inserted into central space **16** and their circumferential grooves are aligned with the arcuate projections **18***a* and **18***b* on opposite sides **20** and **22** of the segments **12** and **14**. Fasteners **34** and **36** are then further tightened to draw segments **12** and **14** toward one another. FIG. **3** shows the point when the first and second action surfaces **42** and **50** on segments **12** and **14** engage one another (**42** shown). Advantageously, support surfaces **44** and **52** on each segment engage at approximately the same time (**44** shown). Arcuate projections **18***a* and **18***b* (not visible in the figure) are also engaged within the grooves of the pipe elements at this point as well. During correct installation of coupling **10**, engagement of the support surfaces **44** and **52** between the segments **12** and **14** provide a first visual indication confirming that correct installation is proceeding.

[0036] The angular orientation and opposite slopes of the action surfaces **42** and **50** and the support surfaces **44** on the first end **28** of the segments and support surfaces **52** on the second end **30** cause the segments **12** and **14** to rotate in opposite directions relatively to one another as fasteners **34** and **36** are further tightened. FIG. **1** illustrates the axis of rotation **66** of the segments as the pair of action surfaces **42** and the pair of action surfaces **50** on each segment engage one another. The object of this rotation is to force the arcuate projections **18***a* and **18***b* to securely contact the sidewalls and/or the floors of the circumferential grooves of the pipe elements which they engage and thereby increase the rigidity of the joint in bending, axial loading, and torsion. Note, however, that the action surfaces **42** and **50** have no feature which limits the degree of relative rotation between the segments **12** and **14** as the fasteners are tightened. A feature which limits the relative rotation between the segments **12** and **14** is provided by the respective stop surfaces **58** and **62** on the lugs **26** and **30**. As shown in FIG. **4**, these stop surfaces (**58** shown) engage as the fasteners are further tightened. The geometry of the action surfaces **42** and **50**, the support surfaces **44** and **52**, and the stop surfaces **58** and **62**, their lengths, positions on the segments and orientation angles are coordinated with the arcuate projections **18***a* and **18***b* such that the projections lock up effectively within the circumferential grooves of the pipe elements when the first stop surfaces **58** and the second stop surfaces **62** respectively engage, or nearly engage as depicted in FIG. **4**. Thus engagement of both stop surfaces **58** and **62** on opposite ends of the segments **12** and **14** provides visual confirmation that the coupling **10** has been properly installed. The stop surface **58** and **62** provide this confirmation over the entire tolerance range imposed on the circumferential grooves in the pipe elements. At one end of the groove tolerance range the segments **12** and **14** rotate about axis **66** to the limit imposed by respective engagement between the first stop surfaces **58** and the second stop surfaces **62**. At the other end of the groove tolerance range engagement between one or both projections **18***a* and **18***b* and their respective circumferential grooves impose the limit on segment rotation. It is conceivable that when engagement between the projections **18***a* and **18***b* and the grooves limits segment relative rotation that one or both of the first and second stop surfaces **58** and **62** will not be engaged. However, the lugs **26** and **30** at opposite ends of the segments **12** and **14** are designed to deform when fasteners **34** and **36** are tightened once the rotational limit imposed by engagement between the projections **18***a* and **18***b* and their circumferential grooves is reached to permit the stop surfaces **58** and **62** to engage. The deformation is controlled in part by the size of the openings **27** and **29** which extend through the lugs **26** and **30**. Thus, regardless of where the circumferential grooves in the pipe elements fall on the tolerance spectrum the technician needs merely to tighten the fasteners **34** and **36** until the stop surfaces **58** and **62** on respective lugs **26** and **30** at respective opposite ends **28** and **32** of segments **12** and **14** engage. This engagement provides a final visual confirmation that the coupling **10** has been properly installed.

[0037] In addition to being readily visually inspected to confirm a proper joint, couplings **10** according to the invention are also relatively insensitive to the installation procedure, affording greater ease of assembly. While a preferred installation practice is to partially tighten each fastener in a series of alternating steps, this practice may not always be followed. Instead, a technician may apply a powered impact wrench and fully tighten one fastener and then the other. However, with couplings **10** according to the invention this practice does not result in over-rotation of the coupling segments, which is prevented by engagement of the stop surfaces on the side of the one fastener which is first tightened. The technician may then apply torque to tighten the other fastener to bring the stop surfaces on the opposite end of the coupling into engagement to complete the installation. The geometry of the couplings is such that as long as both sets of stop surfaces **58** and **62** are in contact, the projections **18***a* and **18***b* will be securely engaged within their respective circumferential grooves, in contact with the groove sidewalls and/or floors to form a rigid joint.

[0038] FIGS. **5-8** illustrate another example embodiment of a coupling **70** according to the invention. Coupling **70** is identical to coupling **10** as described above except for the orientation of the action surfaces **42** and **50**. In coupling **70**, the first action surface **42** is oriented substantially transversely to the longitudinal axis **48** of the first fastener **34** and the second action surface **50** is oriented substantially transversely to the longitudinal axis **56** of said second fastener **36**. Due to the different orientation of the action surfaces **42** and **50** the coupling segments **12** and **14** do not rotate about axis **66** upon their engagement when the fasteners **34** and **36** are tightened to bring the segments toward one another to couple pipe elements to one another. Coupling **70** is advantageous when a more flexible pipe joint is desired. However, when the fasteners **34** and **36** are tightened,

friction between the torqued fastener and its respective lug tends to rotate the coupling segments relatively to one another, thereby causing unwanted engagement between the projections **18***a* and **18***b* and the grooves in the pipe elements. As shown in FIGS. **7** and **8**, this unwanted effect is mitigated by engagement between one or both of the stop surfaces **58** and **62** on the lugs **26** and **30** because the geometry of the support surfaces **44** and **52**, and the stop surfaces **58** and **62**, their lengths, positions on the segments and orientation angles are coordinated with the arcuate projections **18***a* and **18***b* such that the projections will not lock up within the circumferential grooves of the pipe elements when the first stop surfaces **58** and the second stop surfaces **62** respectively engage. Engagement between the stop surfaces and support surfaces may also serve as final visual confirmation that the coupling **70** has been properly installed.
[0039] FIG. **9** illustrates another example embodiment of a coupling **72** according to the invention. Coupling **72** shares many of the features of coupling embodiments **10** and **70** as described above but substitutes a hinge in place of the second lugs **30**. The second ends **32** of each segment **12** and **14**, arranged opposite to the first ends **28**, are connected to a hinge **74** joining the first and second segments to one another. The hinge **74** defines a hinge axis **76** oriented transversely to the longitudinal axis **48** of the first fastener **34**. The first and second segments **12** and **14** are pivotable about the hinge axis **76**. Adjusting the first fastener **34** pivots and thereby draws the first and second segments **12** and **14** toward one another, and engagement between the first stop surfaces **58** on the first lugs **26** (see FIG. **8**) arrests rotation of the segments relatively to one another about the axis **66**. In this example embodiment, hinge **74** comprises bearings **78** (shown) and **80** (hidden) rotatably joined by a hinge pin **82**. Other forms of hinged joints are also practical.
[0040] As for coupling **70**, the first action surfaces **42** of coupling **72** are oriented substantially transversely to the longitudinal axis **48** of the first fastener **34**. Due to the transverse orientation of the action surfaces **42**, the coupling segments **12** and **14** do not rotate relatively to one another about axis **66** upon their engagement when the fastener **34** is tightened to bring the segments toward one another to couple pipe elements to one another. Like coupling **70**, coupling **72** is advantageous when a more flexible pipe joint is desired. When the fastener **34** is tightened, friction between the torqued fastener and its respective lug tends to rotate the coupling segments relatively to one another, thereby causing unwanted engagement between the projections **18***a* and **18***b* and the grooves in the pipe elements. Similar to coupling **70** and shown in FIGS. **7** and **8** (which also illustrate lugs **26** of coupling **72**), this unwanted effect is mitigated by engagement between one or both of the stop surfaces **58** on the lugs **26** because the geometry of the support surfaces **44** and the stop surfaces **58**, their lengths, positions on the segments and orientation angles are coordinated with the arcuate projections **18***a* and **18***b* such that the projections will not lock up within the circumferential grooves of the pipe elements when the first stop surfaces **58** engage. Engagement of the stop surfaces also prevents unwanted torsion loads on the hinge about an axis transverse to rotation axis **76**. Engagement between the stop surfaces and support surfaces may also serve as final visual confirmation that the coupling **72** has been properly installed. The stop surfaces provide this confirmation over the entire tolerance range imposed on the diameter of the circumferential grooves in the pipe elements.
[0041] As with couplings **10** and **70**, the first lugs **26** of coupling **72** define a first opening **27** surrounding a first axis **29** oriented transversely to the longitudinal axis **48** of the first fastener **34**. Axis **48** and fastener **34** are positioned between the first action surfaces **42** and the first support surfaces **44**. In the example embodiment shown the first opening **27** extends through said first lugs **26**. In a practical embodiment, the first adjustable fastener **34** may comprise a nut **38** and bolt **40**.
[0042] FIGS. **10**, **10**A, and **11** show another example embodiment of a coupling **84** for joining pipe elements in end to end relation. Coupling **84** is useful to create a relatively stiff, or rigid joint without inducing rotation of the coupling segments **86**, **88** about axis **66**, through the application of forceful radial contact by the arcuate projections **124** against pipe elements **128** within circumferential grooves **210** as shown in FIG. **10**A. In this example the coupling **84** comprises first

and second segments **86** and **88** attached to one another end to end surrounding a central space **90** for receiving the pipe elements. Each segment **86**, **88** comprises a first lug **92** extending from a first end thereof and a second lug **94** extending from a second end thereof. The first and second lugs of the first segment **86** align respectively with the first and second lugs of the second segment **88**. A first adjustable fastener **96** extends between the first lugs **92** and a second adjustable fastener **98** extends between the second lugs **94**.

[0043] In this example each segment **86** and **88** further comprises a first action surface **100** positioned between the central space **90** and the first lug **92**. Each segment also comprises a first support surface **102** positioned on the first lug **92**. The first fastener **96** is positioned between the first action surface **100** and the first support surface **102**. The first action surface **100** and the first support surface **102** are oriented transversely to a longitudinal axis **104** of the first fastener **96**.

[0044] A second action surface **106** is positioned between the central space **90** and the second lug **94**. A second support surface **108** is positioned on the second lug **94**. The second fastener **98** is positioned between the second action surface **106** and the second support surface **108**. The second action surface **106** and the second support surface **108** are oriented transversely to a longitudinal axis **110** of the second fastener **98**.

[0045] Advantageously, the first lugs **92** may define a first opening **112** surrounding a first axis **114** oriented transversely to the longitudinal axis **104** of the first fastener **96** and positioned between the first action surfaces **100** and the first support surfaces **102**. In a practical embodiment, the first opening **112** extends through the first lugs **92**. The bending stiffness of the first lugs **92** may be tuned to a desired value by properly sizing the first opening **112**. Similarly, the second lugs **94** may define a second opening **116** surrounding a second axis **118** oriented transversely to the longitudinal axis **110** of the second fastener **98** and positioned between the second action surfaces **106** and the second support surfaces **108**. In a practical embodiment, the second opening **116** extends through the second lugs **94**. The bending stiffness of the second lugs **94** may be tuned to a desired value by properly sizing the second opening **116**. Bending of the lugs is effected by the fasteners **96** and **98**, which in this example embodiment comprise a bolt **120** and a nut **122**. Stiffness tuning of the first and second lugs **92** and **94** is used to determine the operation of coupling **84** as described below. In an example embodiment illustrated in FIGS. **11**A and **11**B, the tuning of the lugs **92** on segments **86** and **88** may also include controlling the amount of bending of the lugs by adjusting the sizes of the gap X between first action surfaces **100** relative to the gap Y between first support surfaces **102**, with it being advantageous for the gap Y between the first support surfaces **102** to be greater than the gap X between first action surfaces **100** (FIG. **11**A). The relative gap may be conveniently controlled, for instance, by an offset Z between the first action surfaces **100** and the first support surfaces **102** on one or both segments **86** and **88**, as shown in FIG. **11**B for segment **86**. Offset Z is measured from the first action surface **100**. Similarly, as shown in FIGS. **11**C and **11**D, the tuning of the lugs **94** on segments **86** and **88** may also include controlling the amount of bending of the lugs by adjusting the sizes of the gap X between second action surfaces **106** relative to the gap Y between second support surfaces **108**, with it being advantageous for the gap Y between the second support surfaces **108** to be greater than the gap X between second action surfaces **106** (FIG. **11**C). The relative gap may be conveniently controlled, for instance, by an offset Z between the second action surfaces **106** and the second support surfaces **108** for one or both segments **86** and **88** as shown in FIG. **11**D for segment **86**. Offset Z is measured from the second action surface **106**. As shown in FIGS. **11**E and **11**F, other forms of offsets, such as angular offsets, are feasible to control the manner and form of contact between the first support surfaces and second support surfaces in order to accommodate varying pipe tolerances and materials as described herein. As shown in FIG. **11**E, both the first action surface **100** and the first support surface **102** on lugs **92** respectively on each segment **86** and **88** have respective orientation angles **192** and **194** measured from a plane **196** extending between the segments **86** and **88**. The magnitude of the orientation angles **192** and **194** naturally controls the spacing between first action surfaces **100** and first support surfaces **102** on each segment **86** and **88** when the first lugs **92** are drawn toward one another as the first fastener **96** is tightened. Increasing or decreasing the orientation angles **192** and **194** will concomitantly increase or decrease the separation of the first support surfaces **102** as measured at the point when the first action surfaces **100** come into contact. It is advantageous if the magnitudes of both angles **192** and **194** are substantially equal to one another, although designs wherein the angles **192**, **194** are not the same are contemplated as within the scope of the invention. While the first lugs **92** are illustrated in FIG. **11**E, it is understood that second lugs **94** (see FIG. **11**) may be mirror images of the first lugs and also have angularly oriented second action surfaces and angularly oriented second support surfaces the same as or similar to first lugs **92**. FIG. **11**F shows another example embodiment of coupling **84** wherein the first action surfaces **100** on first lugs **92** of each segment **86** and **88** have respective first orientation angles **195** and **197** (again measured from plane **196**) and first support surfaces **102** on first lugs **92** of each segment **86** and **88** have respective second orientation angles **199** and **201** measured from plane **196**. The magnitudes of the orientation angles **195**, **197**, **199** and **201** naturally control the spacing between first action surfaces **100** and first support surfaces **102** on each segment **86** and **88** when the first lugs **92** are drawn toward one another as the first fastener **96** is tightened. Increasing or decreasing the orientation angles **195**, **197**, **199** and **201** will concomitantly increase or decrease the separation of the first support surfaces **102** as measured at the point when the first action surfaces **100** come into contact. Furthermore, the use of different orientation angles between the action surfaces **100** and the support surfaces **102** is expected to provide greater variability and thus increase the ability to fine tune the behavior of the segments **86** and **88**. Although only first lugs **92** are shown, it is understood that second lugs **94** (see FIG. **11**) may be mirror images of the first lugs and also have angularly oriented second action surfaces and angularly oriented second support surfaces the same as or similar to the first lugs **92**.

[0046] As shown in FIG. **10**, each segment **86**, **88** of the example coupling **84** according to the invention comprises first and second arcuate projections **124** positioned on opposite sides of the segments. Each of the arcuate projections **124** faces the central space **90**, and each of the arcuate projections is engageable within circumferential grooves in the pipe elements (not shown) when the segments are drawn toward one another by the adjustable fasteners **96** and **98** to connect the pipe elements end to end.

[0047] Coupling **84** may further comprise a seal **126** positioned within the central space **90**. When coupling **84** is provided in a “factory pre-assembled state” (segments **86** and **88** connected end to end surrounding the central space **90**) seal **126** may be used to support the segments **86** and **88** in spaced apart relation sufficient to permit insertion of the pipe elements into the central space **90** without disassembling the coupling. Seal **126** engages the pipe elements and the segments to ensure a fluid tight joint.

[0048] Coupling **84** is designed to produce a relatively rigid joint between the pipe elements over a broad tolerance range of groove diameters while still permitting visual indication that a proper joint has been formed. FIGS. **12** and **13** illustrate coupling **84** engaging a pipe element **128** having a groove diameter at the lower end of the groove diameter tolerance range. Pipe element **128** has been inserted into the central space **90** and the fasteners **96** and **98** have been tightened to first bring the arcuate projections **124** into forceful contact with outer surfaces of the pipe elements within the grooves, such that continued tightening results both the first action surfaces **100** on each segment **86** and **88** being brought into close juxtaposition or into contact and the second action surfaces **106** on each segment being brought into close juxtaposition or into contact, as shown in FIG. **12**. The bending stiffness of the lugs **92** and **94** is tuned such that further tightening of fasteners **96** and **98** will bring both the first support surfaces **102** on each segment **86** and **88** into contact and the second support surfaces **108** on each segment into contact. In an embodiment, the amount of tightening required to bring both the first support surfaces **102** into contact may be controlled or affected by the relative gap X between the first action surfaces and the gap Y between the first support surfaces. This first configuration is shown in FIG. **13** and visually signals a completed joint for a pipe element at the lower end of the groove diameter tolerance range by contact between the first support surfaces **102** and the second support surfaces **108**.

[0049] FIGS. **14** and **15** illustrate coupling **84** engaging a pipe element **130** having a groove diameter at the higher end of the groove diameter tolerance range. Pipe element **130** has been inserted into the central space **90** and the fasteners **96** and **98** have been tightened to bring the arcuate projections **124** on each segment **86** and **88** into engagement with the groove of the pipe element **130**. Action surfaces **100** on each segment **86** and **88** may not contact one another at the high end of the groove diameter tolerance range; neither may action surfaces **106** come into contact. This is evidenced in FIG. **14** by the gaps **132**, **134** which appear respectively between the first action surfaces **100** as well as the second action surfaces **106**. The bending stiffness of the lugs **92** and **94** is tuned such that further tightening of fasteners **96** and **98** will bring both the first support surfaces **102** on each segment **86** and **88** into contact and the second support surfaces **108** on each segment into contact. This second configuration is shown in FIG. **15** and signals a completed joint for a pipe element at the higher end of the groove diameter tolerance range. For such pipe elements a completed joint is visually indicated by contact between the support surfaces **102** and **108** on each segment, the gaps **132** and **134** remaining. The tuned behavior of the lugs **92** and **94** reduce the potential for over-torquing fasteners **96** and **98**, as the technician can visually confirm that a proper joint has been formed when the support surfaces are in contact.

[0050] The configurations described in FIGS. **12-15** are illustrative of certain tolerance conditions, and the range of tolerance conditions encountered in field applications is contemplated within the scope of the invention, including tolerance conditions in between those illustrated, as are variations of the above configurations. As one example, it may be desirable in the small pipe tolerance case described FIGS. **12** and **13** for first action surfaces **100** and second action surfaces **106** to only come into partial or line contact, or even only close juxtaposition in order that the forceful contact between the coupling segments and the pipe elements be relatively maximized, and not prematurely limited by contact between those action surfaces, as maximum forceful contact increases the rigidity of the joint. It is further expected that during the tightening sequence, deformation will occur in the segments **86** and **88**, pipe element **128**, or both depending on the relative stiffness of the components, the thickness and material of the pipe, as well as the precise tolerance condition of the specific components employed.

[0051] FIG. **16** illustrates another example embodiment of a coupling **136** according to the invention. The first and second segments **138** and **140** of coupling **136** comprise respective first lugs **142** and **144**, each having action surfaces **146**, support surfaces **148**, and tuned bending stiffnesses capable of assuming the first and second configurations (described above) providing a visual indication of a proper joint depending upon the groove diameter of the pipe element. Unlike coupling embodiment **84**, coupling **136** substitutes a pivotal arrangement, such as hinge **150**, in place of the second lugs. Hinge **150** defines a hinge axis **152** oriented transversely to the longitudinal axis **154** of the fastener **156** (in this example, a bolt and nut) extending between lugs **142** and **144**. The first and second segments **138** and **140** are pivotable about the hinge axis **154**. Adjusting the fastener **156** pivots and thereby draws the first and second segments **138** and **140** toward one another, and into engagement with the pipe element **158** and into either one of the first or second configurations depending upon the where in the tolerance range the groove diameter of the pipe element falls. In this example embodiment, hinge **150** comprises cantilevers **160**, **162** engaging one another at a fulcrum **164**. Cantilevers **160**, **162** are joined by a ring **166**, retained by projecting heads **168**, **170** on each cantilever. Other forms of hinged joints, such as saddle and stirrup hinges, pinned hinges, cast hinges, and the like, are also practical.

[0052] Example coupling **136** employs a pivotal arrangement with a fulcrum **164** in place of the second lugs, wherein the tuning of the lugs **142** and **144** on segments **138** and **140** may also include controlling the amount of bending of the lugs by adjusting the sizes of the gap **147** between action surfaces **146** relative to the gap **149** between support surfaces **148**. Such tuning may be accomplished by forming action surfaces **146** and support surfaces **148** to be substantially parallel to respective rays **151**, **153** extending from fulcrum **164**, it being understood that such an arrangement creates an effective offset between action support surfaces **148** and action surfaces **146**. In another example embodiment of coupling **136** shown in FIG. **16**A, it may be advantageous for the gap **149** between the support surfaces **148** to be greater than the gap **147** between action surfaces **146** by forming the support surfaces **148** parallel to rays **155** and **157** respectively, and the action surfaces **146** parallel to rays **159** and **161**, where rays **155**, **157** subtend a larger angle between them than do rays **159**, **161**. FIG. **16**B shows another example embodiment wherein rays **155** and **157** subtend a smaller arc than rays **159** and **161** resulting the gap **149** being less than the gap **147**. This arrangement is expected to be useful for creating flexible couplings where the keys have limited contact with the pipe in order to permit the pipes to move angularly and axially to an extent relative to the coupling. When used with the negative offset as shown in FIG. **16**B, the support surfaces **148** will contact before the action surfaces **146**, visually indicating that assembly is complete before the coupling is forcefully gripping the pipe enough to inhibit the desired flexibility. Other forms of offsets, such as planar offsets, are feasible to control the manner and form of contact between the first support surfaces and to accommodate varying pipe tolerances and materials as described herein.

[0053] Each segment of coupling **136** also comprises first and second arcuate projections **172**, **174** positioned on opposite sides of the segments. The arcuate projections face the central space **90** and are engageable within circumferential grooves in the pipe elements when the segments are drawn toward one another by the adjustable fastener **156**. A seal **176** may be positioned within the central space **90**. The seal may be used to support the segments **138**, **140** in spaced apart relation sufficient to permit insertion of the pipe elements into the central space **90** without disassembling the coupling **136**.

[0054] Couplings according to the invention are also contemplated as being used with a variety of formed pipe ends, such as grooved pipe elements (FIG. **10**A), shouldered pipe elements, and other forms of pipe ends known in the art, including those which are designed to be retained within the coupling. As shown in FIGS. **17** and **18**, the use of plain end pipe elements **200** is also contemplated, in which case the arcuate projections **180** may be provided with teeth **182** as shown on example coupling **184** (FIG. **17**), or, arcuate projections **186** may be provided with retaining rings **188**, as shown on example coupling **190**. Couplings according to the invention having tuned bending of the lugs permits the relative rigidity/flexibility of the joint to be selected by the coupling designer by controlling when in the tightening sequence that contact between the support surfaces occurs, as tightening of the fasteners prior to such contact tends to further enwrap the pipe element with the coupling segments, including increasing the engagement of the arcuate projections with the pipe elements, while continued tightening after such contact occurs tends to compress the lugs rather than act to further engage the arcuate projections with the pipe elements.

[0055] It is expected that couplings according to the invention will permit both rigid and flexible joints to be formed easily and reliably while reducing the coupling's sensitivity to poor installation techniques.

[0056] All of the embodiments of the claimed invention described herein are provided expressly by way of example only. Innumerable variations and modifications may be made to the example embodiments described herein without departing from the concept of this disclosure. In particular, surfaces or axes described as having a perpendicular or parallel relationship may vary from those conditions while still being within the scope of the invention. Additionally, the scope of this disclosure is intended to encompass any and all modifications and combinations of all elements, features, and aspects described in the specification and claims, and shown in the drawings. Any and all such modifications and combinations are intended to be within the scope of this disclosure.

Claims

1. A coupling for joining pipe elements in end to end relation, said coupling comprising: first and second segments attached to one another end to end surrounding a central space for receiving said pipe elements, each said segment comprising a first lug extending from a first end thereof and a second lug extending from a second end thereof, said first and second lugs of said first segment aligning respectively with said first and second lugs of said second segment; a first adjustable fastener extending between said first lugs and a second adjustable fastener extending between said second lugs; wherein each said segment further comprises: a first action surface positioned between said central space and said first lug, and a first support surface positioned on said first lug, said first fastener being positioned between said first action surface and said first support surface, said first action surface and said first support surface being oriented transversely to a longitudinal axis of said first fastener; a second action surface positioned between said central space and said second lug, and a second support surface positioned on said second lug, said second fastener being positioned between said second action surface and said second support surface, said second action surface and said second support surface being oriented transversely to a longitudinal axis of said second fastener.
2. The coupling according to claim 1, wherein said first support surface of at least one of said segments is offset from said first action surface of said at least one segment, said offset being measured from said first action surface.
3. The coupling according to claim 2, wherein said second support surface of said at least one segment is offset from said second action surface of said at least one segment, said offset of said second support surface being measured from said second action surface.
4. The coupling according to claim 1, wherein said first support surface of at least one of said segments is oriented at a first orientation angle measured with respect to a plane extending between said first and second segments.
5. The coupling according to claim 4, wherein said first action surface of said at least one segment is oriented at a second orientation angle measured with respect to said plane.
6. The coupling according to claim 5, wherein said first orientation angle is equal to said second orientation angle.
7. The coupling according to claim 1, wherein: said first action surface and said first support surface of said first segment are oriented at a first orientation angle measured with respect to a plane extending between said first and second segments; said first action surface and said first support surface of said second segment are oriented at a second orientation angle measured with respect to said plane; said second action surface and said second support surface of said first segment are oriented at a third orientation angle measured with respect to said plane; said second action surface and said second support surface of said second segment are oriented at a fourth orientation angle measured with respect to said plane.
8. The coupling according to claim 1 wherein said first lugs are adapted, upon tightening of said first adjustable fastener, to assume either a first configuration, wherein said first action surfaces are in contact with one another and said first support surfaces are in contact with one another, or a second configuration, wherein said first support surfaces are in contact with one another, there being a gap between said first action surfaces.
9. The coupling according to claim 8 wherein said second lugs are adapted, upon tightening of said second adjustable fastener, to assume either a first configuration, wherein said second action surfaces are in contact with one another and said second support surfaces are in contact with one another, or a second configuration, wherein said second support surfaces are in contact with one another, there being a gap between said second action surfaces.
10. The coupling according to claim 1, wherein said first lugs define a first opening surrounding a

first axis oriented transversely to said longitudinal axis of said first fastener and positioned between said first action surfaces and said first support surfaces.

11. The coupling according to claim 10, wherein said first opening extends through said first lugs.

12. The coupling according to claim 10, wherein said second lugs define a second opening surrounding a second axis oriented transversely to said longitudinal axis of said second fastener and positioned between said second action surfaces and said second support surfaces.

13. The coupling according to claim 12, wherein said second opening extends through said second lugs.

14. The coupling according to claim 1, wherein each one of said first and second adjustable fasteners comprises a nut and bolt.

15. The coupling according to claim 1, wherein each of said segments comprises first and second arcuate projections positioned on opposite sides of said segments, each of said arcuate projections facing said central space, each of said arcuate projections being engageable within circumferential grooves in said pipe elements when said segments are drawn toward one another by said adjustable fasteners.

16. The coupling according to claim 1, further comprising a seal positioned within said central space, said seal supporting said segments in spaced apart relation sufficient to permit insertion of said pipe elements into said central space without disassembling said coupling.

17. A coupling for joining pipe elements in end to end relation, said coupling comprising: first and second segments attached to one another end to end surrounding a central space for receiving said pipe elements, each said segment comprising a first lug extending from a first end thereof, said first lug of said first segment aligning with said first lug of said second segment; an adjustable fastener extending between said first lugs; each said segment further comprising a second end, said second ends of said segments arranged opposite to said first ends respectively, each said second end connected to a hinge joining said first and second segments to one another, said hinge defining a hinge axis oriented transversely to a longitudinal axis of said first fastener, said first and second segments being pivotable about said hinge axis; wherein each said segment further comprises: an action surface positioned between said central space and said first lug, and a support surface positioned on said first lug, said first fastener being positioned between said action surface and said support surface, said action surface and said support surface being oriented transversely to said longitudinal axis of said fastener.

18. The coupling according to claim 17, wherein said support surface of at least one of said segments is offset from said action surface of said at least one segment, said offset being measured from said action surface.

19. The coupling according to claim 17, wherein said action surface and said support surface on said first segment are oriented parallel to a first ray extending from a fulcrum of said hinge, and said action surface and said support surface on said second segment are oriented parallel to a second ray extending from said fulcrum of said hinge.

20. The coupling according to claim 17, wherein: said action surface on said first segment is oriented parallel to a first ray extending from a fulcrum of said hinge; said support surface on said first segment is oriented parallel to a second ray extending from said fulcrum of said hinge; said action surface on said second segment is oriented parallel to a third ray extending from said fulcrum of said hinge; said support surface on said second segment is oriented parallel to a fourth ray extending from said fulcrum of said hinge.

21.-**28**. (canceled)