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Mach

(54) COLD FORGED STUB END

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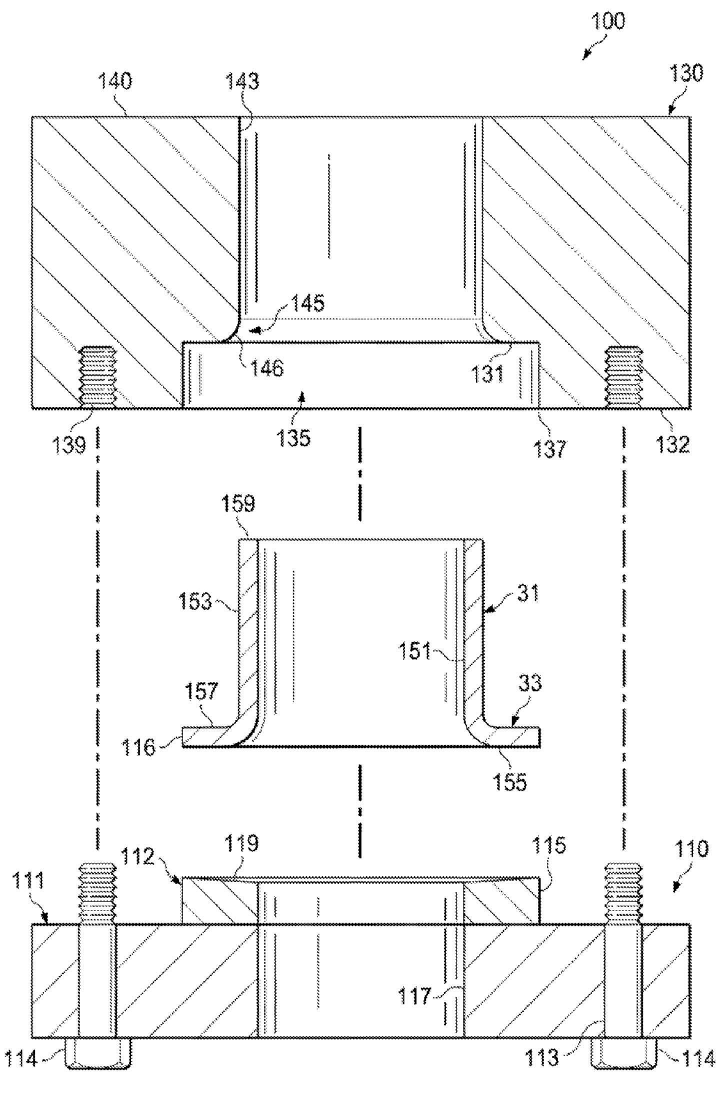
(57) ABSTRACT

Apparatus for forming and shaping a stub end fitting and methods for forming the stub end fitting, are provided. The apparatus can include application of a multi-part die including first and second die parts which both together contain a preformed stub end fitting having an annular shaped flange, and a third die part ("push bullet") used to land upon an end of a tubular member opposite the flange of the stub end fitting in order to cause portions of the stub end fitting to extrude into a cavity between the first and second die portions not already filled by the stub end fitting during initial containment. The resulting stub end fitting has enhanced material and operational properties. Additional material can be added to the outer diameter portion of the stub end fitting between the tubular main body and the flange to build or enhance an existing annular fillet to further enhance the material and operational properties of the stub end fitting.



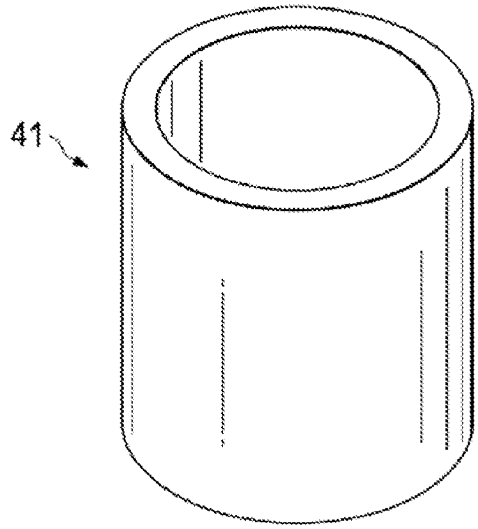


FIG. 1A

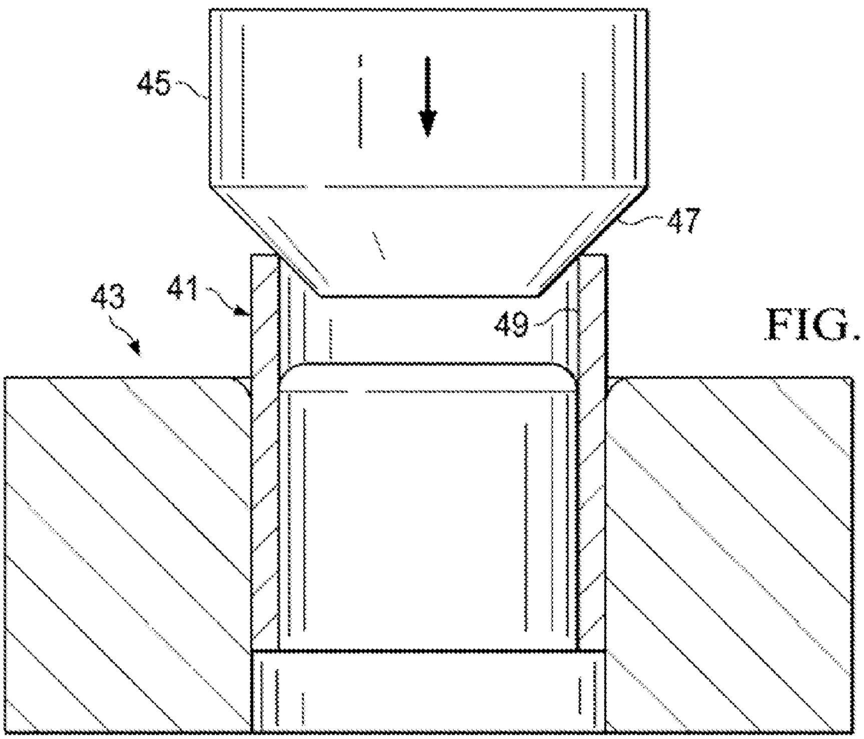


FIG. 1B

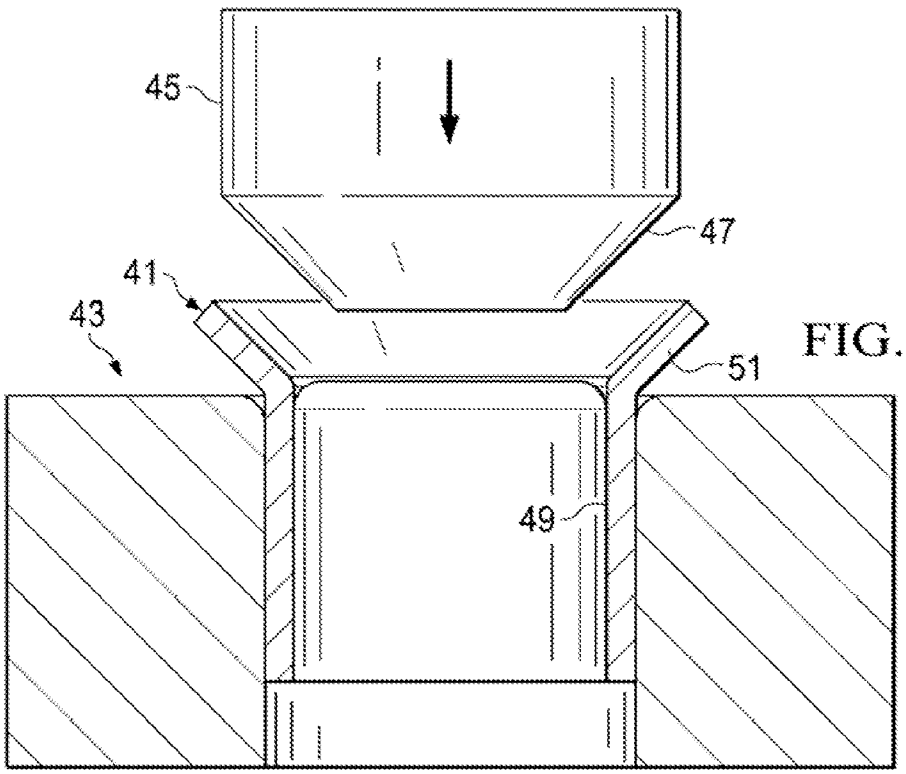


FIG. 1C

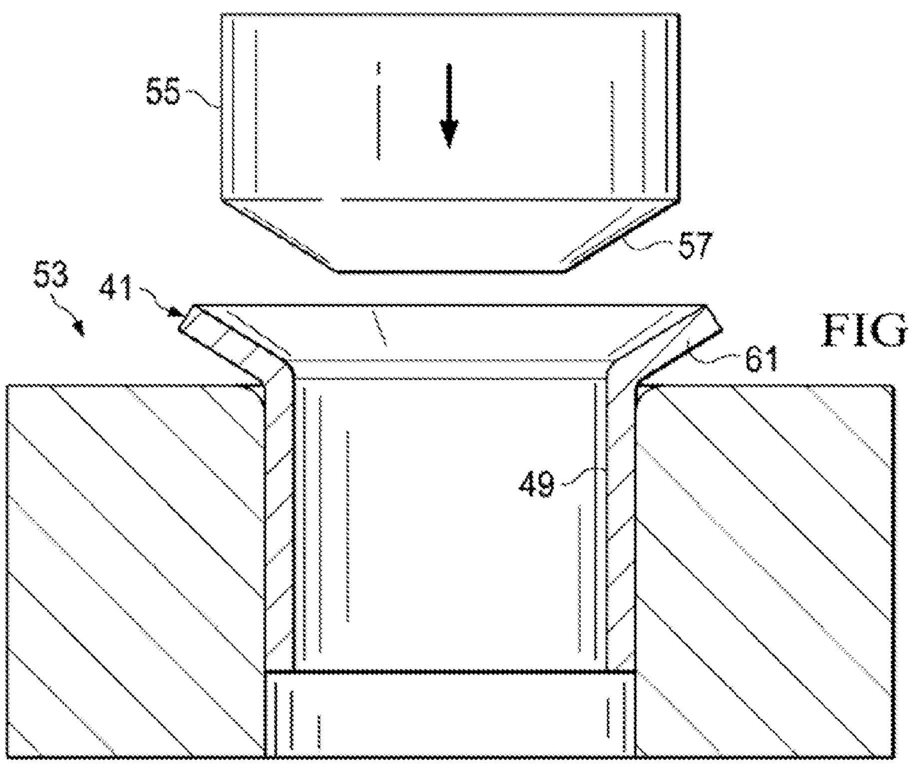


FIG. 2

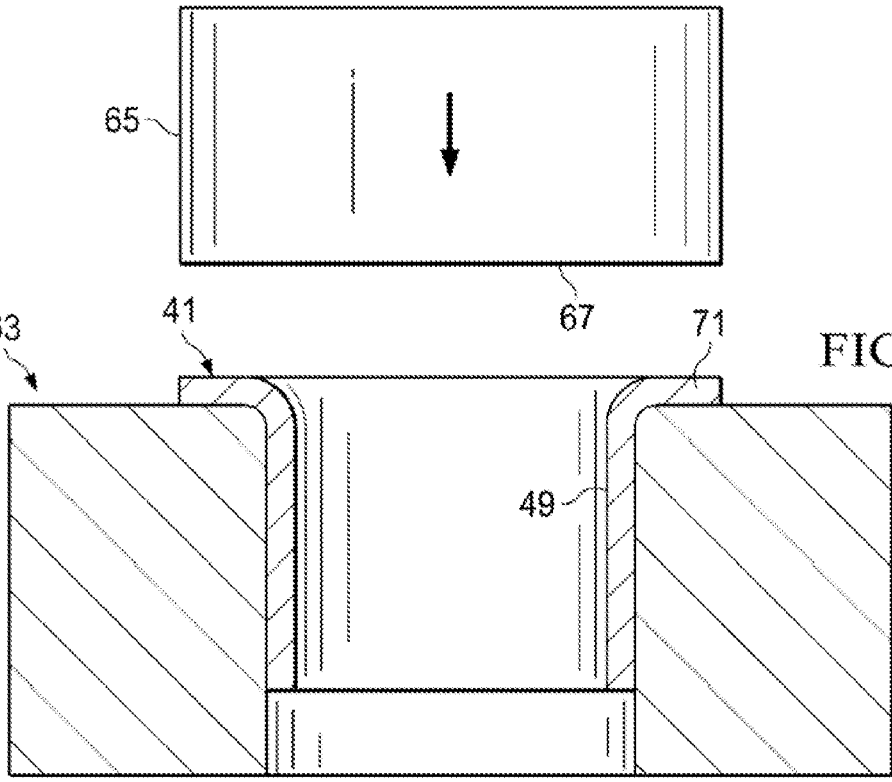


FIG. 3

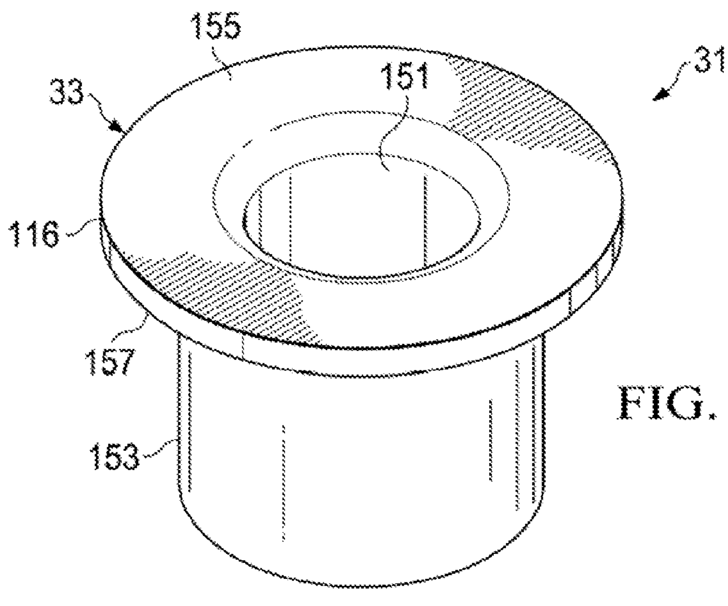


FIG. 4

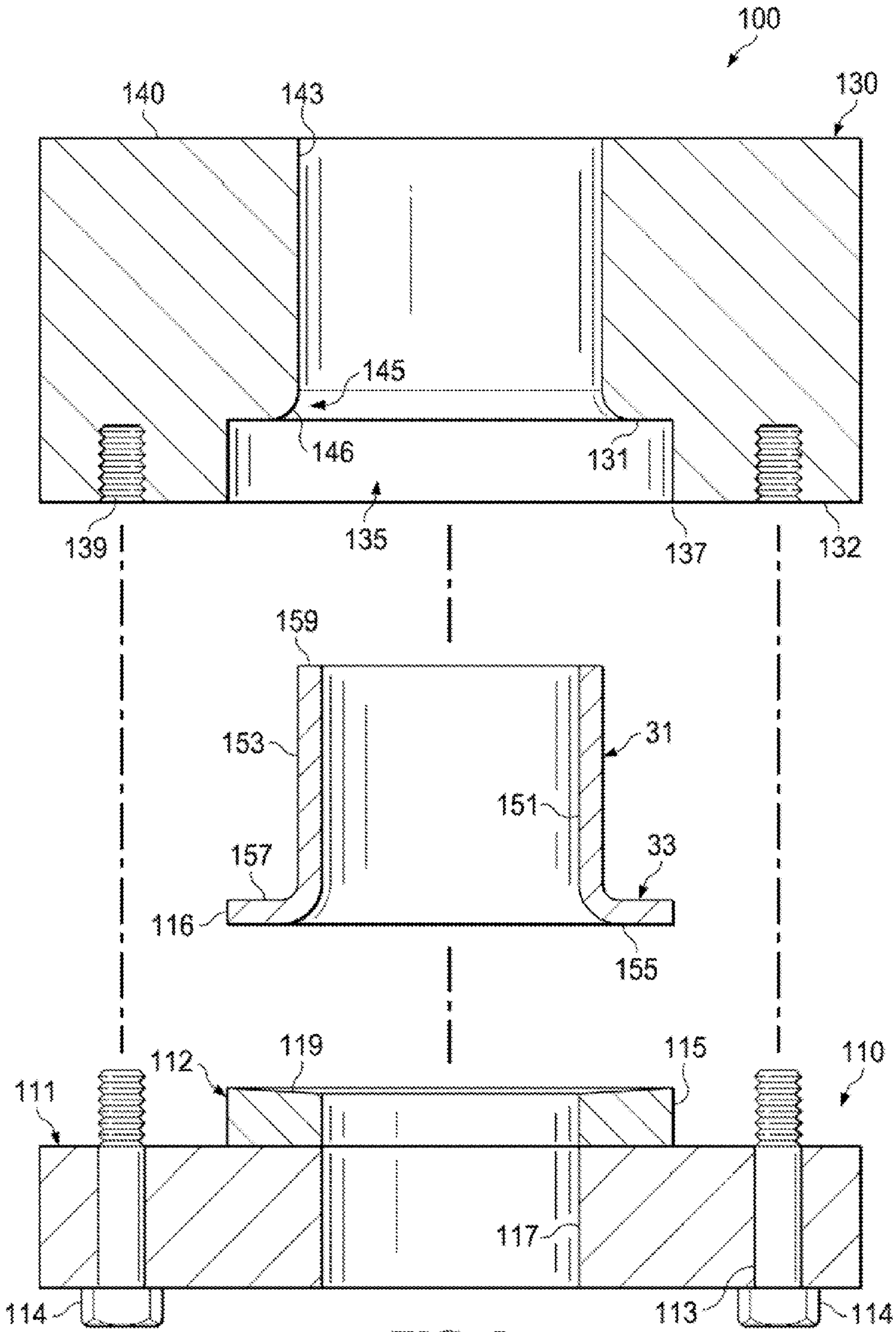

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FIG. 5

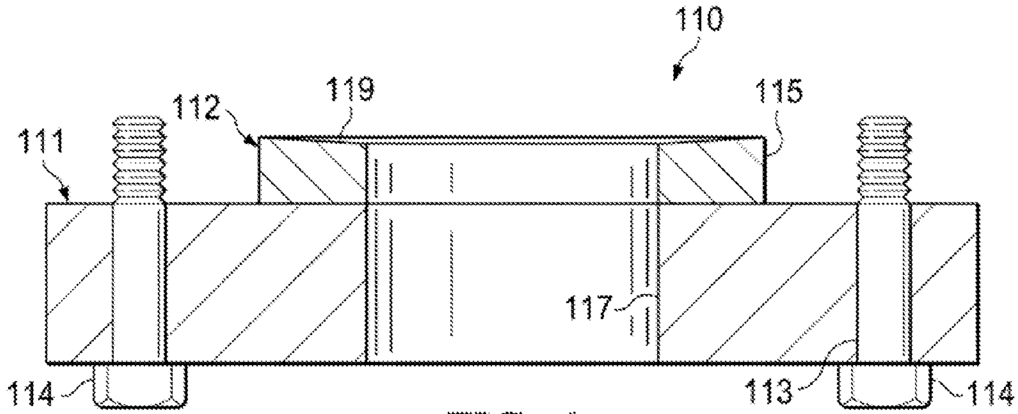
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FIG. 6

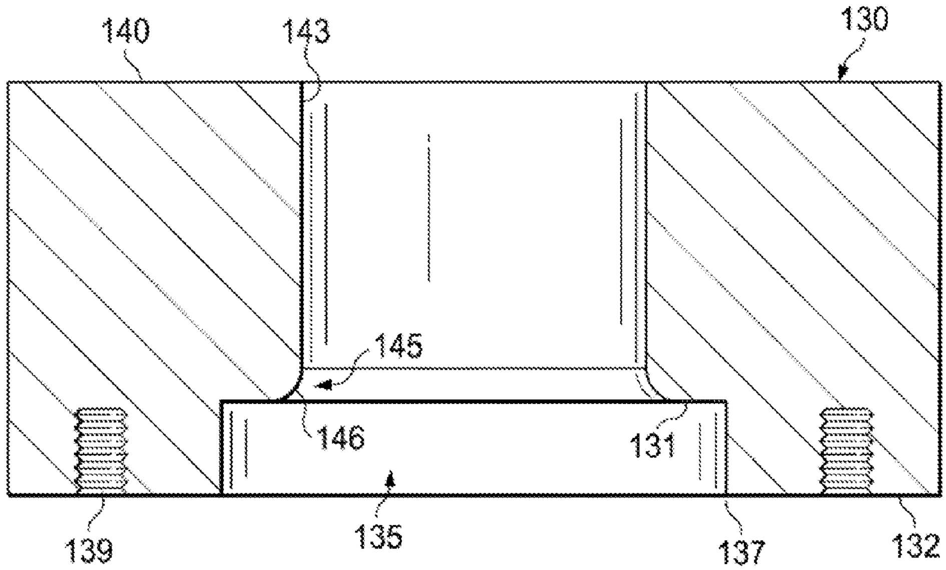
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FIG. 7

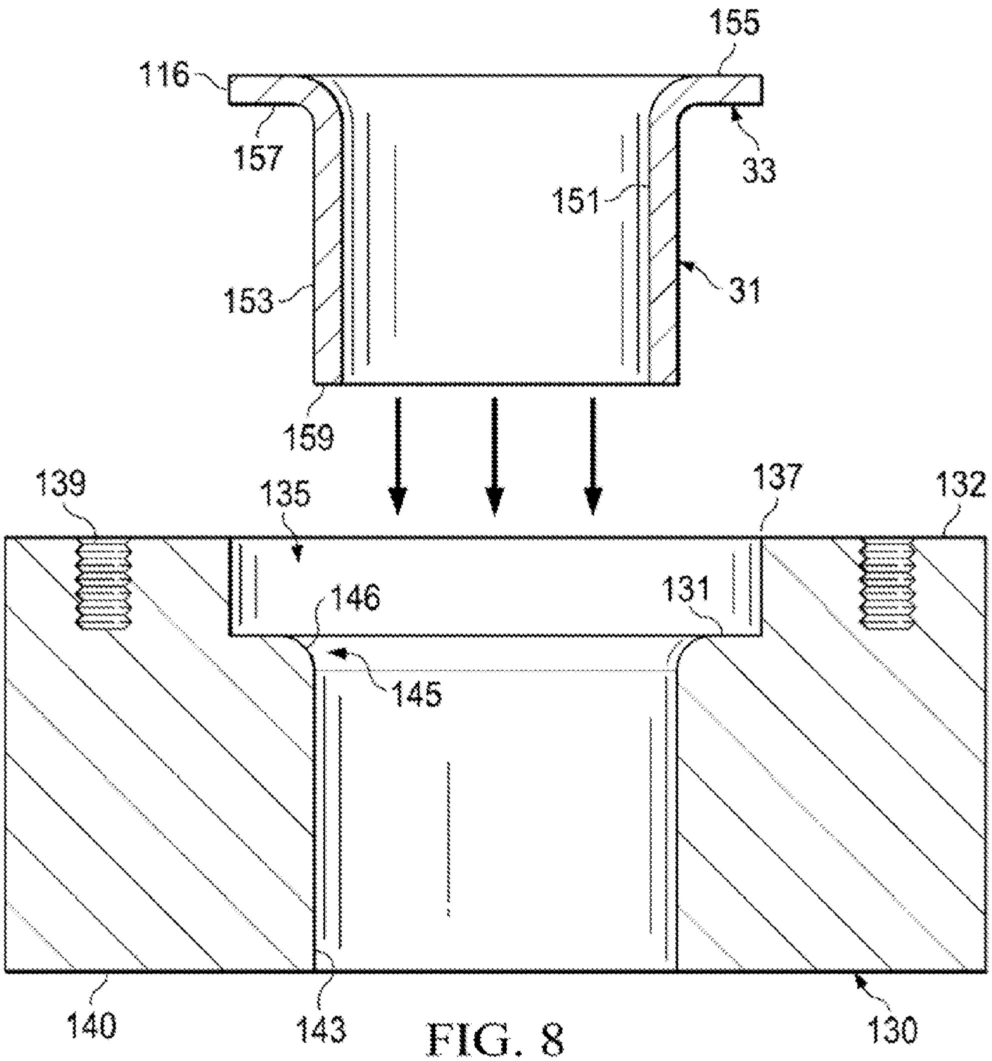

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FIG. 8

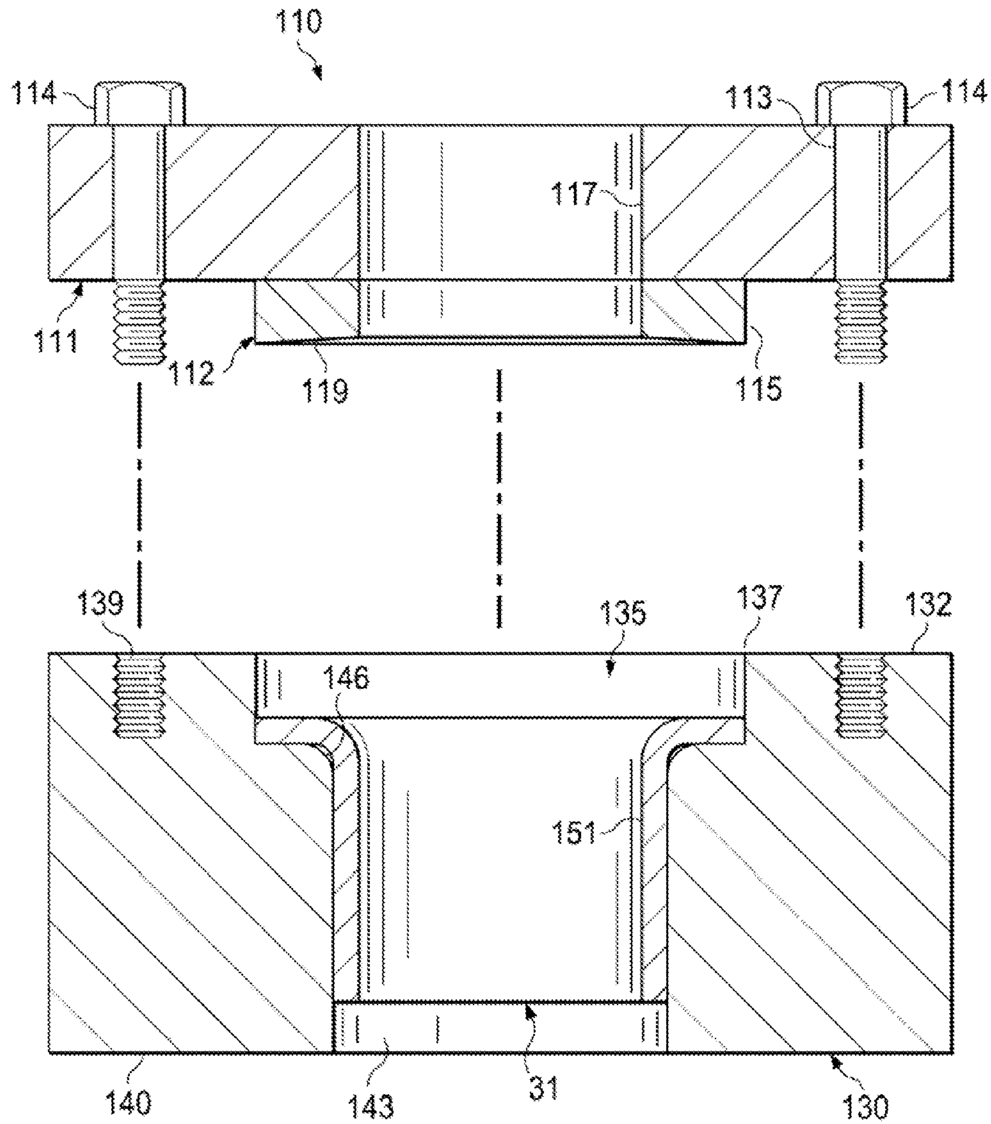
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FIG. 9

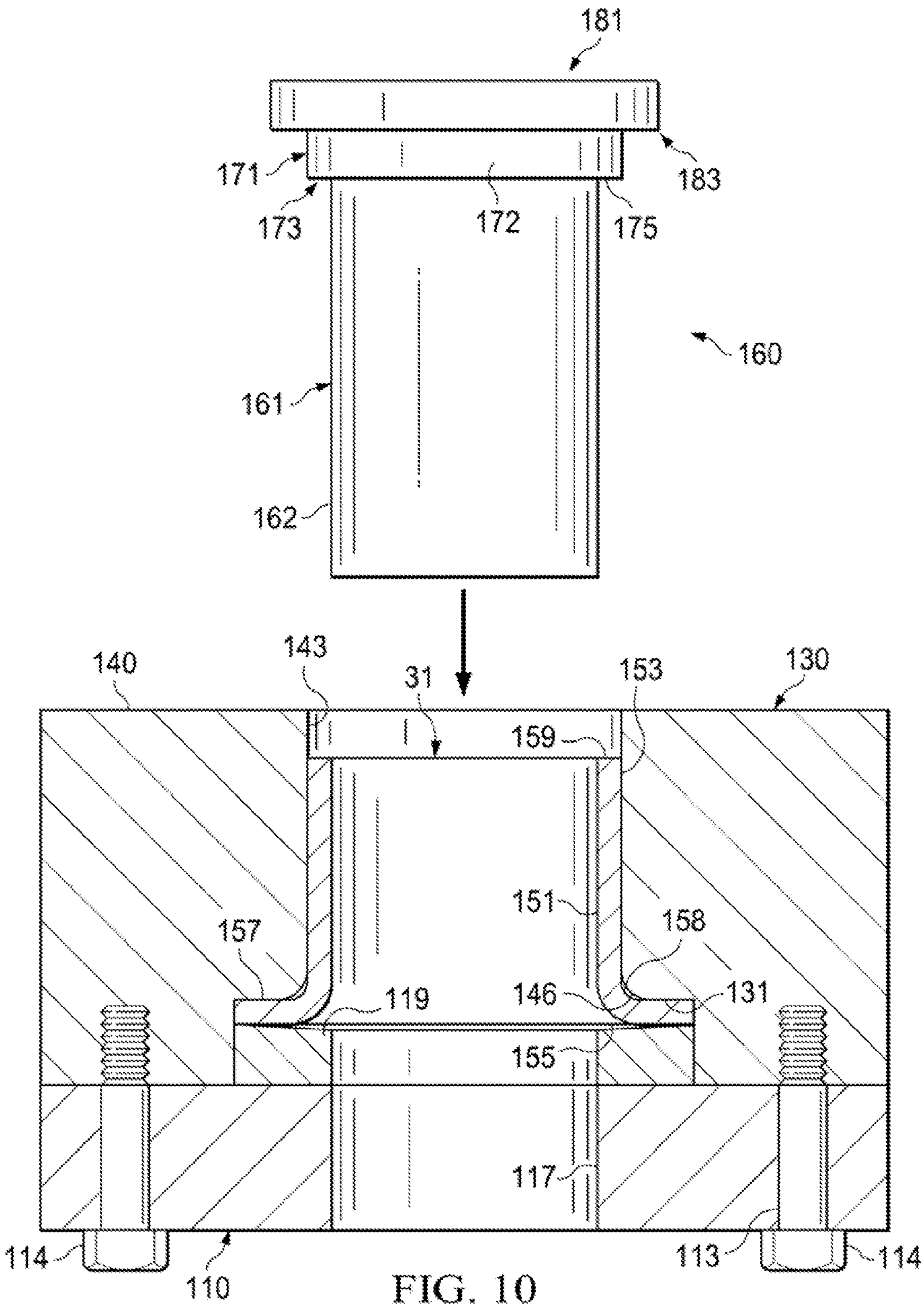
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FIG. 10

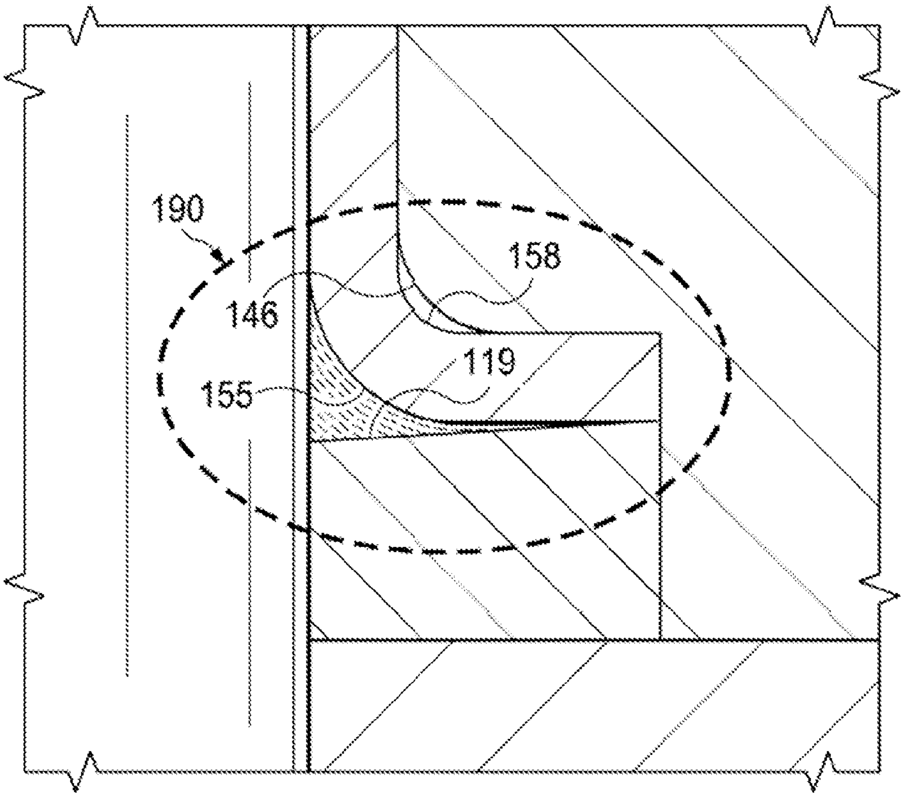

FIG. 11

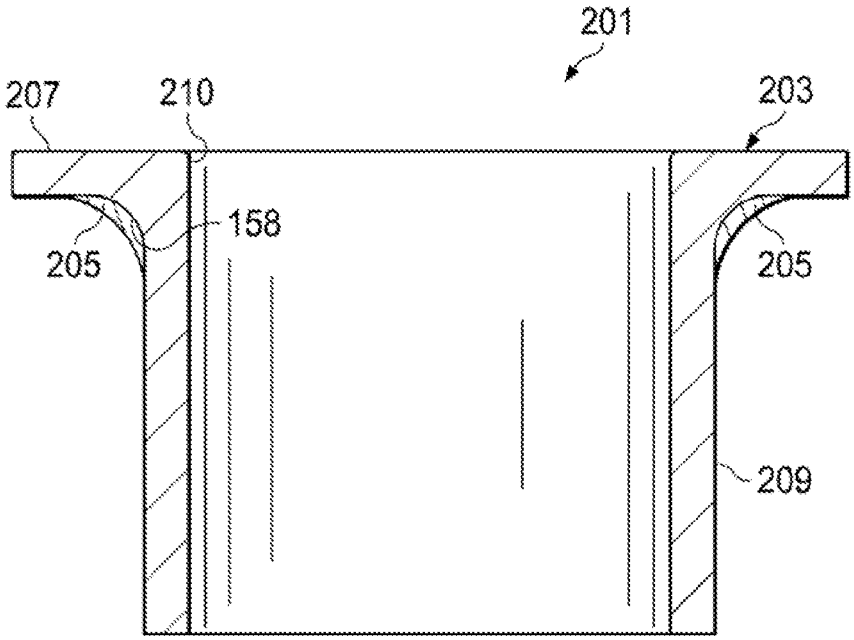

FIG. 12

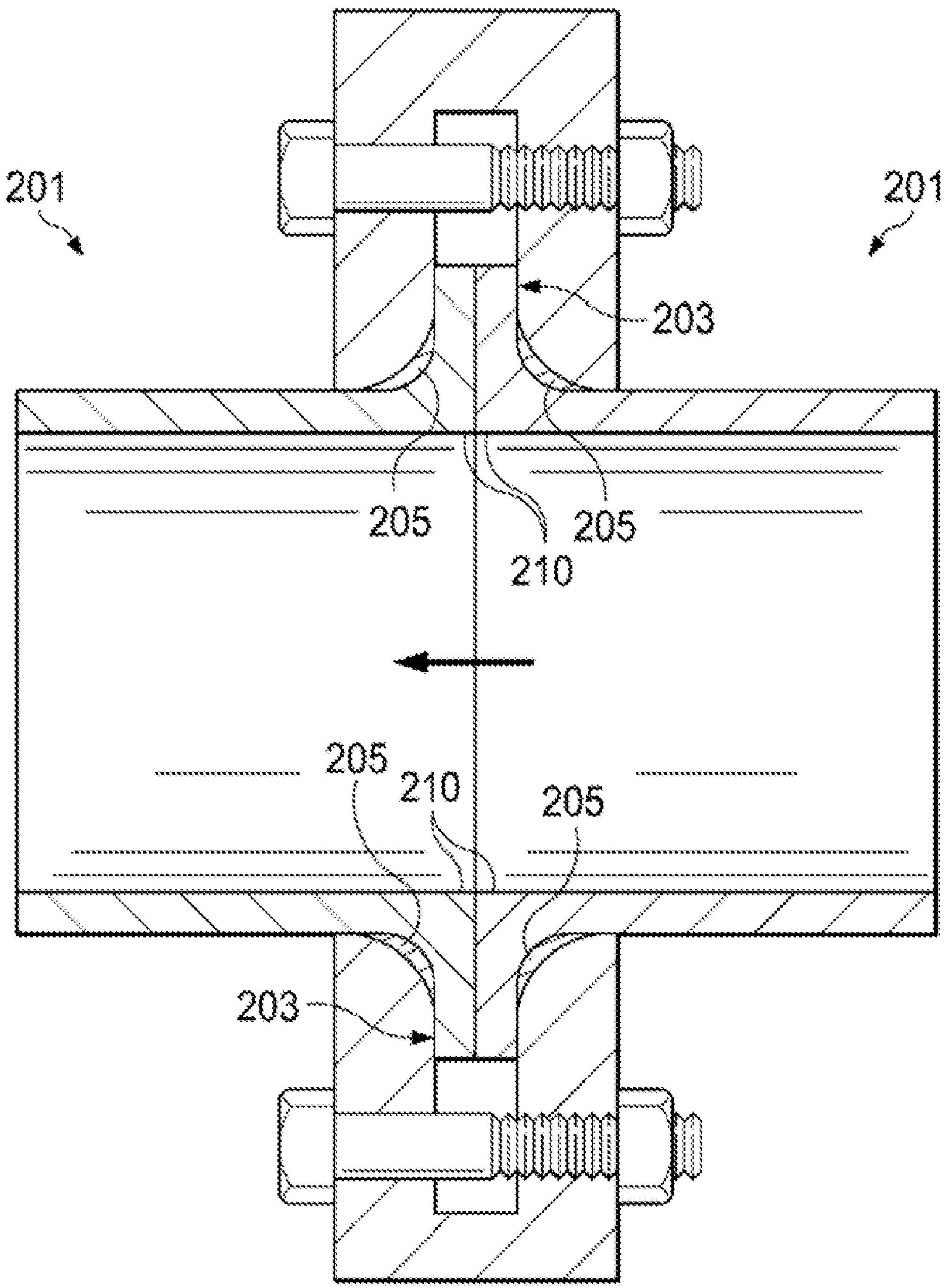

FIG. 13

COLD FORGED STUB END

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to pipes and pipe fittings. More particularly, the present invention relates to systems, apparatus, and related methods for forming a stub end fitting.

[0003] 2. Description of Related Art

[0004] Flare fittings on the ends of adjacent pipes, are used in conjunction with an external compression assembly to connect adjacent pipes together. In order to connect soft copper tubing such as, for example, that used in plumbing or break lines, etc. the end of the copper tubing is first cut to have a smooth surface, and a dowel or punch is used to flare or bend the prepared end of the tubing into a conical shape, typically having a 45 degree angle. A flare nut is then threadingly connected to an adjacent threaded nipple to compress the end of the tubing sufficient to form a leak-tight seal between the conical end of the copper pipe and a surface within the nipple, but not to an extent that the conical end of the tubing is bent normal to the axis of the copper tubing. Notably, such process is effective in typical plumbing and automotive break lines, etc., but would not be effective in connecting adjacent pipes in a plant or facility where the pipes are made of steel or other less pliable material, are generally much larger, function under higher flow rates and pressures, and require substantially non-turbulent fluid flows.

[0005] In a typical connection between, for example, 304L grade stainless steel pipe used in a facility or plant, each of a pair of adjacent pipe ends are fitted with a washer-like flange referred to as a flare fitting, stub end, or stub end fitting having a relatively flat in-line surface normal to the longitudinal axis of the pipe and configured to be held against the stub end of the adjacent pipe with a connection assembly to form a leak-tight seal. In a typical manufacturing process, a washer-like piece of steel or other material to form the flange of the stub end fitting is cut from a flat metal work piece having a thickness matching the desired thickness of the stub end. The washer-like piece forming the flange of the stub end is then welded to the end of a tubular member of the stub end. The stub end fitting is then welded to the end of the pipe. A connection assembly having a complementary pair of connectors are then fitted together such that inner portions press tightly against the stub end of each adjacent pipe end. A series of bolts are inserted through the pair of connectors to compressibly hold the two ends of the pipe together.

[0006] Notably, such arrangement can have some substantial disadvantages. For example, the weld connecting the flange of the stub end to the respective tubular member end extends into the inner diameter of the junction between the tubular member and the flange, making weld inspection a difficult and/or expensive process, which can require substantial interruption of plant or facility operations. Further, imperfections in and between the inner diameter of the flange of the stub end, the portion of the tubular member welded to the pipe end, and in the weld, itself, can result in disruption of what would otherwise remain a laminar flow. Accordingly, recognized by the inventor is the need for a method and apparatus for forming a stub end for the end of the pipe which does not require an annular weld be placed on the inner diameter of the tubular member/stub end, which provides a uniform inner diameter between portions of the stub end and portions of the pipe end adjacent to the stub end that minimizes or limits flow disruption beyond that conventionally capable, and which can be made inexpensively.

SUMMARY OF THE INVENTION

[0007] In view of the foregoing, various embodiments of the present invention advantageously provide a method and apparatus for forming a stub end fitting for use on the end of a pipe, such as, for example, ASA/ANSI 304L grade stainless steel pipe, which does not require the use of a weld to attach the flange of the stub end fitting to the end of the tubular member of the stub end fitting, and/or which does not require an annular weld be placed on the inner diameter of the tubular member/flange conjunction. Various embodiments of the present invention advantageously also or alternatively provide a method and apparatus for forming a stub end fitting for use on the end of a pipe which provides a uniform inner diameter between portions of the flange of the stub end and portions of the tubular member of the stub end that minimizes or limits flow disruption beyond that conventionally capable, and which can be provided a substantial reduction in manufacturing costs.

[0008] Specifically, an embodiment of the present invention provides a method of forming a metal stub end fitting for a pipe. The method can include forming a circumferentially extending flange on a distal end of a tubular member, with the flange and the tubular member defining a junction with an interior radius. The method can also include providing a die having a cylindrical chamber with proximal and distal ends, inserting the tubular member into the distal end of the chamber with the flange in contact with the distally facing surface, and securing a closure plate to a distal side of the die, trapping the flange within a cavity between a distally facing surface located within an annular chamber having a cylindrical inner diameter substantially equal to an outer diameter of the flange, and a face on the closure plate having a frusto-conical shape. The method can also include providing a plunger having a cylindrical portion and an external annular shoulder, inserting the cylindrical portion of the plunger into the tubular member and past the flange, engaging a proximal end of the tubular member with the external shoulder, and applying a force that shortens a length of the tubular member and causes metal at the junction to flow, decreasing the interior radius and causing the distally facing surface of the flange to become frusto-conical. The method further includes the steps of machining the distally facing surface of the flange to a flat surface, applying a weld bead around an exterior fillet joining the flange with the tubular member, and machining the weld bead to a desired radius for the exterior fillet.

[0009] An embodiment of the present invention provides an apparatus for shaping an annular shaped flange on an end of a tubular member. The apparatus can include a multi-part die including first and second die parts which can be connected together to contain a preformed shaped stub end fitting, and a third die part defining a push bullet which can be used to modify the stub end fitting through application of the force on an end of the tubular member opposite the flange of the stub end fitting to cause portions of the flange and/or portions of the adjacent tubular member to extrude into a cavity (e.g., gaps) between the first and second die portions not already filled by the stub end fitting during initial containment.

[0010] According to an exemplary configuration, the first die part has: a first proximal facing surface shaped to receive a first distal facing surface of a second die part; a second proximal facing surface adjacent the first proximal facing surface and positioned to receive a distal facing surface of a stub end fitting when positioned in the multi-part die; a distal surface; and a cylindrical shaped bore extending at least partially therebetween along a main axis thereof, with at least substantial portions of the cylindrically shaped bore having inner surface dimensions substantially matching inner surface dimensions of a bore extending through a main body and a preformed stub end fitting. According to the exemplary configuration, the first proximal facing surface is longitudinally separated from and coaxially located with the second proximal facing surface and has an inner diameter at least as large as, but more preferably matching the outer diameter of the second proximal facing surface. The second proximal facing surface has an outer diameter substantially matching an outer diameter of the flange of the stub end fining when completed and has a uniform inward slope extending between surfaces forming an outer perimeter of the second proximal facing surface and surfaces forming an inner perimeter of the second proximal facing surface adjacent the bore to form a conical face.

[0011] Further, according to an exemplary configuration, the second die part has a first distal facing surface being shaped to land on the first proximal facing surface of the first die part; a second distal facing surface adjacent the first distal facing surface and positioned to land on at least portions of a proximal facing surface of the stub end fitting when positioned in the multi-part die; a proximal facing surface; and a cylindrically shaped central bore extending along a main axis of the second die part between the proximal facing surface and the second distal facing surface. At least substantial portions of the bore of the second die part have inner surface dimensions substantially matching outer surface dimensions of the main body of the tubular member. The second die part also includes an annular shaped recess extending axially inward from the inner perimeter of the first distal facing surface to form the second distal facing surface. According to the exemplary configuration, the first distal facing surface is longitudinally separated from and coaxially located with the second distal facing surface and has an inner diameter at least as large as but preferably matching the outer diameter of the second distal facing surface, and has an outer diameter substantially matching an outer diameter of the stub end fitting when completed. The recess is coaxially located with the central bore and includes portions having an inner perimeter dimension matching an outer perimeter dimension of the second distal facing surface and outer perimeter dimension of the stub end fitting when completed and a diameter that is larger than the diameter of the central bore, such that the larger diameter recess in conjunction with a smaller diameter central bore form an annular shoulder having a rounded corner having a specified radius being smaller than a radius of the stub end fitting when completed.

[0012] Still further, according to an exemplary configuration, the push bullet (third die part) includes a cylindrically shaped first main body portion having a cylindrically shaped side outer surface being shaped to match the inner surface dimensions of the cylindrically shaped bore extending at least partially through the first die part along a main axis thereof and substantially matching inner surface dimensions of the bore extending through the main body and the stub end fitting of the preformed tubular member. The push bullet further includes a cylindrically shaped second main body portion having side outer surface dimensions matching inner surface dimensions of the cylindrically shaped central bore of the second die part and outer surface dimensions of the main body of the tubular member, whereby the larger side outer surface dimensions of the cylindrically shaped second main body portion in conjunction with a smaller side outer surface portions of the first main body portion form an annular shoulder having a distal facing surface configured to land upon an annular shaped proximal facing surface of the preformed tubular member.

[0013] According to the exemplary method of use of the above described multi-part die, the cylindrically shaped first and second main body portions of the push bullet can be slidably positioned within the centrally shaped central bore of the second die part so that the second main body portion provides compression of the tubular member along the main axis of the first and second die parts, the main axis of the push bullet, and the main axis of the preformed tubular member to thereby induce metal flow to fill gaps between portions of the proximal facing surface of the first die part and distal facing surface of the flange and/or gaps between portions of the annular shoulder of the second die part and portions of the tubular member between an outer surface of the main body of the tubular member and the proximal facing surface of the stub end fitting of the tubular member. Advantageously, the first main body portion of the push bullet is slidably positioned within the bore of the first die part and the bore of the tubular member during compression to prevent radially inward flow of tubular member material during compression of portions of the tubular member. A proximal portion of the push bullet can have outer surface dimensions being larger than the outer surface dimensions of the first main body portion of the push bullet to form a shoulder defining a stop positioned to limit axial movement of the second main body portion of the push bullet into the cylindrically shaped bore of the second die part during the compression-metal extrusion process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] So that the manner in which the features and advantages of the invention, as well as others which will become apparent, may be understood in more detail, a more particular description of the invention briefly summarized above may be had by reference to the embodiments thereof which are illustrated in the appended drawings, which form a part of this specification. It is to be noted, however, that the drawings illustrate only various embodiments of the invention and are therefore not to be considered limiting of the invention's scope as it may include other effective embodiments as well.

[0015] FIG. **1**A is a perspective view of a portion of a tubular member having a uniform inner and outer diameter;

[0016] FIG. **1**B is a sectional view of a first stage die having the tubular member of FIG. **1**A positioned therein;

[0017] FIG. **1**C is a sectional view of the tubular member positioned in the first stage die of FIG. **1**B after application of a bending force to form a flare in the end of the tubular member;

[0018] FIG. **2** is a sectional view of the tubular member positioned in a second stage die after application of a bending force to widen the flare of the tubular member shown in FIG. **1**C;

[0019] FIG. **3** is a sectional view of the tubular member positioned in a third stage die after application of a bending force to form a stub end fitting;

[0020] FIG. **4** is a perspective view of a stub end fitting after removal from the third stage die of FIG. **3**;

[0021] FIG. **5** is an exploded sectional view of a preformed stub end fitting positioned in a multi-part die according to an embodiment of the present invention;

[0022] FIG. **6** is a sectional view of a portion of the first die part of the multi-part die according to an embodiment of the present invention;

[0023] FIG. **7** is a sectional view of a portion of the second die part of the multi-part die according to an embodiment of the present invention;

[0024] FIG. **8** is a sectional view of a preformed stub end fitting being positioned in the bore of the second die part of the multi-part die according to an embodiment of the present invention;

[0025] FIG. **9** is a partially exploded sectional view of the first die part of the multi-part die being landed upon the second die part of the multi-part die to contain a preformed stub end fitting according to an embodiment of the present invention;

[0026] FIG. **10** is a partially exploded sectional view of a third die part being inserted into the combined first and second die parts of the multi-part die after rotation thereof according to an embodiment of the present invention;

[0027] FIG. **11** is a sectional view illustrating metal extrusion within a cavity formed by a combination of the first and second die parts of the multi-part die according to an embodiment of the present invention;

[0028] FIG. **12** is a sectional view of the stub end fitting after removal from the multi-part die shown in FIG. **11** according to an embodiment of the present invention; and

[0029] FIG. **13** is a sectional view illustrating connection of two stub end fittings manufactured in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

[0030] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, which illustrate embodiments of the invention. This invention may, however, be embodied in many different forms and should not be construed as limited to the illustrated embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

[0031] FIGS. **1-13** illustrate various embodiments of: an apparatus comprising a multi-part die **30** configured to shape an annular shaped stub end fitting for use on an end of a pipe and associated methods of shaping an annular shaped stub end fitting. As will be described in more detail below, a multi-part die **30** is configured to receive a preformed stub end fitting having a flange being integral with a main body of a tubular member and having a distal face substantially parallel with a plane that is substantially normal to a main axis of the tubular member. Beneficially, according to the illustrated embodiments of the apparatus and methods, the inner diameter of the flange of the finished stub end is generally uniform throughout and has a same inner diameter as the main body of the tubular member in order to maintain a laminar flow when fluid is flowing therein and when operably connected to a complimentary annular shaped stub end fitting of an adjacent pipe. Below is described three major categories of processes used to obtain the final stub end fitting design. The first describes an example of a methodology of forming a tubular member without a flange. The second describes an example of a methodology of forming a flange that is integral with the main body of the tubular member. The third describes performing enhancements to a conventional preformed stub end fitting which results in a finished stub end fitting having superior structural and operational properties.

[0032] Tubular Member Formation.

[0033] The table below provides a high-level summary of one example of a process for forming a tubular member **41** (see, e.g., FIG. **1**A) having smooth inner and outer diameter surfaces from a flat plate, according to a specific example. It should be noted that one of ordinary skill in the art would understand there are various other methodologies of forming a tubular member having smooth inner and outer diameter surfaces, often referred to as a BTS tube/pipe, and that the example provided is but one example of many. The exemplary steps for the example process are as follows:

Step # 0:	Obtain a disc to size.
Step # 1:	Push using required first stage die.
Step # 2:	Penetrant testing (PT) examine ends prior to heat treatment. Machine square off only any crack indications prior to heat treat.
Step # 3:	Heat treat at solution anneal temp of e.g., 1900° F. or other appropriate temperature and water quench.
Step # 4:	Aluminum oxide blast first stage cup.
Step # 5:	Push using second stage bullet (male) and required second stage die (female).
Step # 6:	PT examine the second stage prior to heat treatment before machine square off. Machine only those ends that show crack indications. Machine crack indications 100% off as necessary.
Step # 7:	Heat treat crack free second stage at solution anneal temp 1900° F. or other appropriate temperature.
Step # 8:	Aluminum oxide blast second stage cup.
Step # 9:	PT examine ends of second stage before pushing third stage. Machine off any crack indications.
Step # 10:	Push third stage using the third stage bullet (male) and required third stage die (female).
Step # 11:	PT examine ends of third stage-machine off any crack indications. No machining if no crack indications.
Step # 12:	Optionally: Heat treat crack free third stage.
Step # 13:	Aluminum oxide blast third stage cup.
Step # 14:	Saw off flat end leaving as much length as possible. Saw blade passes next to inner diameter end.
Step # 15:	Deburr saw cut end.

[0034] Preform Stub End Formation

[0035] As noted above, according to an embodiment of the present invention, a tube/tubular member **41** (see, e.g., FIG. **1**A) having smooth inner and outer diameter surfaces is obtained either as described above or according to various methods as known and understood by one of ordinary skill in the art to include the various methodologies of cold forging, hot forging, and molding, among others. Regardless of the method of obtaining a tube/tubular member **41**, according to an embodiment of the present invention, an end of the tube/tubular member is flared to form a flange **33** of a stub end fitting **31**. The table below provides a high-level summary of a process for forming a stub end fitting **31** including a flange **33** having a flat plate radius as measured between the resulting inner diameter and outer diameter so that the flange **33** is integral with the main body of the stub end fitting **31**:

Step # 0:	Obtain BTS tube/pipe/tubular member.
Step # 1:	Push in first stage flare die. Ensure desired amount extends out of die. Ensure sure thickest wall end (side opposite saw cut end) extends out of the die.
Step # 2:	Optional: Heat treat first stage flare at solution anneal temp 1900° F. or other appropriate temperature and water quench.
Step # 3:	Push in second stage flare die.
Step # 4:	Push in third stage flare die.
Step # 5:	Heat treat third stage flare at solution anneal temp 1900° F. or other appropriate temperature and water quench.
Step # 6:	Aluminum oxide blast third stage flare.
Step # 7:	Machine OD of flange to fit into final forming die. The maximum tolerance for OD should generally not exceed the desired outer diameter. The minimum tolerance is typically approximately −1/16" or as otherwise desired, depending upon the size of the OD.
Step # 8:	Full machine OD and ID of part.

[0036] As provided in the example and table above and as perhaps best shown in FIGS. **1A-C**, a tube/tubular member **41** having smooth inner and outer diameter surfaces is obtained and positioned within a first stage flare die **43** to produce an initial bend forming a flare in the end of the tube/tubular member **41**. In the specific illustrated example, the tubular member **41** is positioned so that a portion of the thickest wall end (normally the side opposite the saw cut end) extends out of the die **43**. A punch **45** having a frustoconical end portion **47** having a cone angle of approximately 30 degrees is inserted into the bore **49** of the end portion of the tube/tubular member **41** to form a flare **51** of approximately 30 degrees. Optionally, the tube/tubular member having first stage flare can then be removed and heat treated at a solution anneal temp of 1900° F. or other appropriate temperature depending upon the materials used, and water quenched.

[0037] As perhaps best shown in FIG. **2**, the tube/tubular member **41** is then positioned in a second stage flare die **53**. A punch **55** having a frustoconical end portion **57** having a cone angle of approximately 60 degrees is landed upon the upward facing surface of the flare **51** to expand the flare **51** to form a flare **61** of approximately 60 degrees.

[0038] As perhaps best shown in FIG. **3**, the tube/tubular member **41** is then positioned in a third stage flare die **63**. A punch **65** having a substantially flat end portion **67** is landed upon an upward facing surface of the flare **61** to form a flange **71** having flare of approximately 90 degrees. The tube/tubular member **41** having third stage flare is then removed from the third-stage flare die **63** and heat treated at a solution anneal temp of 1900° F. or other appropriate temperature, water quenched, and provided an aluminum oxide blast. A pipe technician then machines off the outer diameter of the flange **71** to fit into a final forming die **100** (see, e.g., FIG. **5**). The result is the stub end fitting **31** illustrated in FIG. **4**. Note, in the specific illustrated embodiment, the stub end fitting **31** is machined to have an outer diameter having a value of between that of the inner diameter of the inner bore of die **100** and a value slightly smaller. Note also, due to limitations of the bending process, the stub end fitting **31** generally has a large interior radius between the newly created flange **33** and the remaining tubular portion.

[0039] Stub End Enhancement

[0040] As noted above, according to an embodiment of the present invention, a BTS tube with flange/stub end fitting **31** at least substantially oriented normal to the main axis of the stub end fitting **31** (a.k.a. an upset preform) shown in FIG. **4** is obtained according to various methods as known and understood by those of ordinary skill in the art. Regardless of the method of obtaining the flanged tube/pipe defining the stub end fitting **31**, however, according to an embodiment of the present invention, the flanged end of the stub end fitting **31** is modified to form a stub end fitting **201** (see e.g., FIGS. **12** and **13**) including a flange **203** having a fillet **205** of a desired thickness and radius and/or a chamfer (not shown) having desired thickness and angle or other appropriate shape; an integral inside radius at **210** matching the inner diameter of the main body **209** of the fitting **201** and free of any weld material; and an enhanced microstructure that has superior structural and operational properties. The table below provides a high-level summary of a process for shaping an annular flange **33** to have precise dimensions and metallurgy exceeding that conventionally capable:

Step # 0:	Obtain BTS tube/pipe having substantially flat flange.
Step # 1:	Set all bolts in upset die.
Step # 2:	Flip die to accept push bullet.
Step # 3:	Push to depth on bullet. Bullet will bottom out on bottom of female upset die. If blank is too long the tonnage will spike very fast before bottom is reached as die cavity is completely filled.
Step # 4:	Un-bolt and push upset form out of die.
Step # 5:	Weld build up fillet: single pass gas metal arc welding (MIG). two passes gas tungsten arc welding (GTAW).
Step # 6:	Rough machine fillet.
Step # 7:	PT examine fillet: straighten flange as necessary.
Step # 8:	Heat treat final form at solution anneal temp 1900° F. or other suitable temperature.
Step # 9:	Full machine OD and ID of part.

[0041] As provided in the example and table above and as perhaps best shown in FIGS. **5-11**, a perform BTS tube/forming a preform stub end fitting **31** having substantially flat flange **33** is obtained and positioned in a final stage multi-part die **100**. In an exemplary embodiment of the present invention, the first die part **110** of the multi-part die **100** has first and second main body portions **111**, **112**. The first main body portion **111** is positioned to connect with a second die part **130** and includes, for example, multiple (e.g. eight) bores **113** for receiving a corresponding series of bolts **114** extending through to the second die part **130**, described in more detail later. The second main body portion **112** has a cylindrically shaped side **115** having side outer surface dimensions matching side outer surface dimensions of an outer surface **116** of the annular flange **33** on the end of the stub end fitting **31** and matching radial inner surface dimensions of substantial portions of an annular shaped recess **135** extending axially inward from, e.g., the inner perimeter **137** of a second distal facing surface **132** of the second die part **130**, which surrounds the first distal facing surface **131**. The second main body portion **112** also has a cylindrically shaped bore **117** extending at least partially therethrough along a main axis of the first die part **110** and substantially matching inner surface dimensions of a bore **151** extending through a main body (tubular member) **153** and the flange **33** of the stub end fitting **31**. The second main body portion **112** further has a proximal facing surface **119** configured to receive a distal facing surface **155** of the flange **33** of the stub end fitting **31** during shaping thereof and having an outer diameter substantially matching an outer diameter of the flange **33** when completed.

[0042] As perhaps best shown in FIG. **6**, according to the exemplary configuration, the proximal facing surface **119** has a uniform inward slope extending between surfaces forming an outer perimeter of the proximal facing surface **119** adjacent side **115** and surfaces forming an inner perimeter of the proximal facing surface **119** adjacent the bore **117** to form a conical face. In a preferred configuration, the uniform inward slope of the conical face of the second proximal surface **119** is a minimum of between approximately eight degrees and a maximum of approximately 15 degrees, although other slope angles are within the scope of the present invention.

[0043] Referring again to FIG. **5**, the second die part **130** has multiple (e.g. eight) threaded bores **139** for receiving a corresponding series of bolts **114** extending through the first die part **110**. The second die part **130** also has a proximal facing surface **140**, a first distal facing surface **131** positioned to land on at least portions of a proximal facing surface **157** of the flange **33** when positioned in the multi-part die **100**, and a cylindrically shaped central bore **143** extending along a main axis of the second die part **130** between the proximal facing surface **140** and the first distal facing surface **131**. According to the exemplary configuration, the first distal facing surface **131** has an outer diameter substantially matching an outer diameter of the flange **33** when completed and the bore **143** has inner surface dimensions matching outer surface dimensions of the tubular main body **153** of the stub end fitting **31**. The second die part **130** also has an annular shaped recess **135** extending axially inward from the second distal facing surface **132** so that the second distal facing surface **132** is longitudinally separated from and coaxially located with the first distal facing surface **131**. The recess **135** has an inner diameter at least as large as, but more preferably, exactly as large as the outer diameter of the first distal facing surface **131**, is coaxially located with the central bore **143**, has an inner perimeter dimension matching an outer perimeter dimension of the second distal facing surface **131** of the second die part **130** and outer perimeter dimension of the flange **33** when completed, and has a diameter being larger than the diameter of the central bore **143**. As perhaps best shown in FIG. **7**, the larger diameter recess **135** in conjunction with a smaller diameter central bore **143** form an annular shoulder **145** having a rounded corner **146** having a radius being larger than a radius of the respective portion of the stub end fitting **31** when finished (see FIG. **12**).

[0044] As perhaps best shown in FIG. **8**, the flanged perform stub end fitting **31** is inserted into the bore **143** of the second die part **130** as shown, and as shown in FIG. **9**, the second main body portion **112** of the first die part **110** is inserted into the recess **135** in the second die part **130**, and each of the bolts **114** are threadingly connected.

[0045] As perhaps best shown in FIG. **10**, the entire assembly shown in FIG. **9** is then reoriented to accept a third portion **160** ("push bullet") of the multi-part die **100**. According to the exemplary configuration, the push bullet **160** has a first main body portion **161** having a cylindrically shaped side outer surface **162** that matches the inner surface dimensions of the cylindrically shaped bore **117** extending at least partially through the first die part **110** and that at least substantially matches inner surface dimensions of the bore **151** extending through the main body **153** and the flange **33** of the stub end fitting **31**. The push bullet **160** also has a second main body portion **171** having a cylindrically shaped side outer surface **172** being shaped to match inner surface dimensions of the cylindrically shaped central bore **143** of the second die part **130** and outer surface dimensions of the main body **153** of the stub end fitting **31**. According to the exemplary configuration, the larger side outer surface dimensions of the cylindrically shaped second main body portion **171** in conjunction with a smaller side outer surface portions of the first main body portion **161** of the push bullet **160** form an annular shoulder **173** having a distal facing surface **175** configured to land upon the annular shaped proximal facing surface **159** of the stub end fitting **31**. Further, a proximal portion **181** of the push bullet **160** can have outer surface dimensions that are larger than the outer surface dimensions of the second main body portion **171** of the push bullet **160** to form a shoulder defining a stop **183** positioned to limit axial movement of the second main body portion **171** of the push bullet **160** into the cylindrically shaped bore **143** of the second die part **130**. The stop **183** can function to limit application of excessive back pressure resulting from attempting to exceed capacity of a cavity **190** (see also FIG. **11**) formed between the first distal facing portion **131** of the second die part **130** and the proximal facing surface **119** of the second main body portion **112** of the first die part **110**.

[0046] Still referring to FIG. **10**, the first and the second main body portions **161**, **171** of the push bullet **160** is slid down the bore **143** of the second die part **130** to land upon the annular shaped proximal facing surface **159** of the stub end fitting **31** to provide compression of the stub end fitting **31** along a main axis of the first, second, and third die parts **110**, **130**, **160** and the main axis of the stub end fitting **31**. Beneficially, this process induces metal flow to fill gaps between portions of the proximal facing surface **119** of the first die part **110** and distal facing surface **155** of the flange **33**, as perhaps best shown in FIG. **11**, and decreases or sharpens the interior radius between the flange **33** and main body **153**. Note, the compression process tends to shorten the length of main body **153**. Accordingly, the length of the main body **153** should be preselected to meet minimum length requirements prior to stub end enhancement.

[0047] According to an embodiment of the present invention, the gap between portions of the annular shoulder **146** of the second die part **130** and portions of the stub end fitting **31** between an outer surface of the main body **153** of the stub end fitting **31** and the proximal facing surface **157** of the flange **33** of the stub end fitting **31** defining an annular shaped fillet **158**, are not tilled or are not completely filled during the extrusion process and will be completed with an external weld, described later. According to another embodiment of the present invention, the extrusion process results in metal flow in both gaps, which together, collectively form a die cavity **190** between the first and the second die parts **110**, **130**.

[0048] Referring again to FIG. **10**, the first main body portion **161** of the push bullet **160** is sized and positioned within the bore **151** of the tubular main body **153** to prevent radially inward flow of metal/material during compression of portions of the stub end fitting **31**. Note, in an exemplary configuration, the push bullet **160** is moved longitudinally at a rate of approximately six to ten inches per minute until engaging (bottoming out upon) the stop **183** or exceeding a maximum force limit which would indicate that the die cavity **190** is completely filled. According to the exemplary configuration, a pressure is applied to the proximal surface **159** of the stub end fitting **31** via the push bullet **160**, sufficient to exceed the yield of the stub end fining **31**. This amount will vary depending upon the alloy used to form the stub end fitting **31** and its size and thickness. Upon completion of the extrusion process, the push bullet **160** is removed, first and second die parts **110**, **130** are unbolted, and the resulting stub end fitting is removed.

[0049] As perhaps best shown in FIG. **12**, according to an embodiment of the present invention, in order to complete the process of forming the stub end fitting **201** having precisely shaped annular flange **203**, the radius of the fillet shown at **158** in FIG. **11** is adjusted. Beneficially, the a larger radius fillet can serve to strengthen the flange **203** according to principles similar to those of use of a truss. Additionally, as part of the completion, the distal facing surface **207** is machined and the flange **203** is straightened, as necessary.

[0050] According to the embodiment of the present invention, described above, the radius of the fillet is adjusted to that shown at indicator **205** through the addition of welding material. That is, weld material is added to the fillet having the radius shown at indicator **158** (FIG. **11**) such that the radius of the fillet or angle of the weld material is increased to a desired radius, angle, and/or depth being larger than that of the preformed fitting **31** and/or the shoulder **146** of the second die part **130**, and correspondingly, the radius of the fillet upon removal from the multi-part die **100**. Alternatively, weld material stock exceeding that shown at indicator **205** is added so that the end-user may modify the radius into its final form, as desired. For example, weld material can be added to form a 45° chamfer/fillet to allow shaping of the fillet as necessary to meet the needs of the end-user.

[0051] According to an exemplary configuration, the welding process includes application of single pass gas metal arc welding (MIG) and two passes gas tungsten arc welding (GTAW), although others are within the scope of the present invention. If to be completed to the specifications of the end-user as part of the manufacturing process, after welding is completed, the fillet **205** can be rough machined, and a technician can then examine the fillet **205** and, if necessary, apply a bending force to straighten the flange **203**. That is, the flange **203** can be straightened so that all portions of the distal facing surface **207** of the stub end fitting **203** lie in the same plane being normal to the main axis of the stub end fitting **201** if not already lying in the same plane. The stub end fitting **201**, in its final form, is then heat treated, for example, at a solution anneal temp of approximately 1900° F. or other appropriate temperature depending upon the type of material used. Upon completion of the annealing process, both the inner and outer diameter of the main body **209** and flange **203** are given the full machining.

[0052] Beneficially, as perhaps best shown in FIG. **13**, due to the precise sizing, adjacent stub end fitting **201** according to the above described process enhance the maintenance of a laminar flow. Stub end fittings **201** made according to the above described process have an inner radius shown at **210** integral with the main body **209** so that the inner diameter of the stub end fitting **201** adjacent the flange **203** at least substantially, but more typically, perfectly matches the inner diameter of the main body **209** without the need for additional buildup or weld material. Stub end fittings **201** made according to the above described process also include enhance structural characteristics. Further, stub end fittings **201** made according to the above described process do not have a weld buildup along the inner diameter of flange **203** that is in direct contact with the flow service (internal service that the stub end is placed in). This characteristic, not available in conventional stub end fittings, can be a particularly beneficial when the flow service is a corrosive service, such as, for example, of an acid (e.g., HCL).

[0053] Embodiments of the present invention provide several advantages. For example, various embodiments of the present invention provide methods and a new multi-part die design which provides a commercially efficient manufacturing process for forming a stub end without the need for welding a flange to a tubular member, without the need for adding welding or buildup material to the inner radius of the flange that could be subjected to direct contact with a corrosive service, and which provides an enhanced microstructure. Advantageously, without a need for applying weld material to build up the inner diameter adjacent the flange inspection complexity and costs can be significantly reduced. Stub ends manufactured according to various embodiments of the present invention can also advantageously enhance fluid flow characteristics of fluid within the pipe when operationally employed, particularly at the point of interface between the main body of the tubular member and the flange, and between adjacent stub ends. Advantageously, as described with respect to the exemplary configuration, the enhancements formed through metal extrusion can be conducted in accordance with a cold forging process without the utilization of an external heat source.

[0054] In the drawings and specification, there have been disclosed a typical preferred embodiment of the invention, and although specific terms are employed, the terms are used in a descriptive sense only and not for purposes of limitation. The invention has been described in considerable detail with specific reference to these illustrated embodiments. It will be apparent, however, that various modifications and changes can be made within the spirit and scope of the invention as described in the foregoing specification. For example, it should be understood that the featured multi-part die can have different sizes to precisely accommodate different sized tubular members and flanges.

That claimed is:

1. A method of forming a metal stub end fitting for a pipe, comprising:

(a) bending a distal end of a tubular member to create a flange, the flange and the tubular member defining a junction with an interior radius; and

(b) placing the flange within a cavity of a die and applying a distally directed force to a proximal end of tubular member while restraining inward deformation of the tubular member, causing the flange to conform to dimensions of the cavity and decreasing the interior radius.

2. The method as defined in claim **1**, wherein the cavity has a distal face that is frusto-conical, causing a distally facing surface of the flange to become frusto-conical.

3. The method as defined in claim **2**, further comprising the step of machining the distally facing surface of the flange to a flat surface.

4. The method as defined in claim **1**, wherein during step (b) the cavity restrains expansion of an outer diameter of the flange.

5. The method as defined in claim **1**, further comprising the step of applying a weld bead around an exterior fillet joining the flange with the tubular member.

6. The method as defined in claim **5**, further comprising the step of machining the weld bead to a desired external radius for the exterior fillet.

7. The method as defined in claim **1**, wherein step (a) comprises deforming the distal end of the tubular member with a conically shaped punch to create a conical flange, then deforming the conical flange with a flat punch to flatten the flange.

8. The method as defined in claim **1**, wherein step (b) creates a sharp interior corner at the junction.

9. A method of forming a metal stub end fitting for a pipe, comprising:

(a) forming a circumferentially extending flange on a distal end of a tubular member, the flange and the tubular member defining a junction with an interior radius;

(b) providing a die having a cylindrical chamber with proximal and distal ends, the distal end being surrounded by a distally facing surface;

(c) inserting the tubular member into the distal end of the chamber with the flange in contact with the distally facing surface;

(d) securing a closure plate to a distal side of the die, trapping the flange within a cavity between the distally facing surface and a face on the closure plate;

(e) providing a plunger having a cylindrical portion and an external annular shoulder, the cylindrical portion of the plunger having an outer diameter substantially equal to an inner diameter of the tubular member; and

(f) inserting the cylindrical portion of the plunger into the tubular member and past the flange, engaging a proximal end of the tubular member with the external shoulder and applying a force that shortens a length of the tubular member and causes metal at the junction to flow, decreasing the interior radius.

10. The method as defined in claim **9**, wherein the face of the closure plate is frusto-conical, causing the distally facing surface of the flange to become frusto-conical.

11. The method as defined in claim **10**, wherein the conical area of the face of the closure plate has a slope in the range from 8 to 15 degrees.

12. The method as defined in claim **10**, further comprising the step of machining the distally facing surface of the flange to a flat surface.

13. The method as defined in claim **9**, wherein the distal end surrounded by the distal facing surface is located within an annular chamber having a cylindrical inner diameter substantially equal to an outer diameter of the flange.

14. The method as defined in claim **9**, further comprising the step of applying a weld bead around an exterior fillet joining the flange with the tubular member.

15. The method as defined in claim **14**, further comprising the step of machining the weld bead to a desired radius for the exterior fillet.

16. The method as defined in claim **9**, wherein step (a) comprises deforming the distal end of the tubular member with a conically shaped punch to create a conical shape to create conical flange, then deforming the conical flange with a flat punch to create the a flat shape for the flange.

17. The method as defined in claim **9**, wherein step (f) creates a sharp interior corner at the junction.

18. A method of forming a metal stub end fitting for a pipe, comprising:

(a) forming a circumferentially extending flange on a distal end of a tubular member, the flange and the tubular member defining a junction with an interior radius;

(b) providing a die having a cylindrical chamber with proximal and distal ends, the distal end being surrounded by a distally facing surface, the distally facing surface surrounding the distal end being located within an annular chamber having a cylindrical inner diameter substantially equal to an outer diameter of the flange;

(c) inserting the tubular member into the distal end of the chamber with the flange in contact with the distally facing surface;

(d) securing a closure plate to a distal side of the die, trapping the flange within a cavity between the distally facing surface and a face on the closure plate, the face of the closure plate being frusto-conical;

(e) providing a plunger having a cylindrical portion and an external annular shoulder, the cylindrical portion of the plunger having an outer diameter substantially equal to an inner diameter of the tubular member;

(f) inserting the cylindrical portion of the plunger into the tubular member and past the flange, engaging a proximal end of the tubular member with the external shoulder and applying a force that shortens a length of the tubular member and causes metal at the junction to flow, decreasing the interior radius and causing the distally facing surface of the flange to become frusto-conical;

(g) machining the distally facing surface of the flange to a flat surface;

(h) applying a weld bead around an exterior fillet joining the flange with the tubular member; and

(i) machining the weld bead to a desired radius for the exterior fillet.

19. The method as defined in claim **18**, wherein step (f) creates a sharp interior corner at the junction.

20. The method as defined in claim **19**, wherein the conical area of the face of the closure plate has a slope in the range from 8 to 15 degrees.

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