A friction pull plug is provided for use in forming a plug weld in a hole in a material. The friction pull plug includes a shank and a series of three frustoconical sections. The relative sizes of the sections assure that a central one of the sections defines the initial contact point between the hole’s sides. The angle defined by the central one of the sections reduces or eliminates chatter as the plug is pulled into the hole.
FRICION PULL PLUG AND MATERIAL CONFIGURATION FOR ANTI-CHATTER FRICION PULL PLUG WELD

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefore.

BACKGROUND OF THE INVENTION

1. Field of the Invention
This invention relates to plugs used in friction pull plug welding. More specifically, the invention is friction pull plug whose lateral surfaces are configured to reduce or eliminate chatter when the plug contacts a material’s hole during a friction pull plug welding process.

2. Description of the Related Art
Friction pull plug welding involves locating a defective region and using a plug to form a hole in a material, and filling the hole with a tapered plug that is friction welded into place. In general, a friction pull plug is rotated at high speeds, e.g., typically several thousand revolutions per minute. As the rotating plug comes into contact with a material’s hole that is to be plugged, tremendous torque and loads are required to maintain the rotational speed of the plug. Any chatter developed during this stage of the process can produce torque that stalls the machine rotating the plug or causes speed fluctuations that can cause variations in the weld’s strength. These problems are exacerbated when a plug’s taper angle is decreased as is generally the case with increasing material thickness.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a friction pull plug that reduces chatter as the plug contacts a hole’s side walls.

Another object of the present invention is to provide a friction pull plug that can be used to effectively plug holes in both thin and thick materials.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

In accordance with the present invention, a friction pull plug is provided for use in forming a plug weld in a hole in a material wherein the hole has a diameter D. The friction pull plug includes a shank having a constant diameter D1, wherein D1>D. A first inverted frustoconical section is coupled to the shank. The first inverted frustoconical section has a smallest diameter D2 wherein D2>D1, and has a largest diameter D3 wherein D3>D2. A second inverted frustoconical section is coupled to the first inverted frustoconical section. The second frustoconical section has a largest diameter D4 wherein D4>D3, and has a smallest diameter D5 wherein D5>D4. The second inverted frustoconical section has a first longitudinal axis and a first lateral surface wherein a first angle defined between the first longitudinal axis and the first lateral surface is between approximately 5° and approximately 7.5°. A third inverted frustoconical section has a second longitudinal axis and a second lateral surface wherein a second angle defined between the second longitudinal axis and the second lateral surface is less than the first angle and is between approximately 5° and approximately 7.5°.

BRIEF DESCRIPTION OF THE DRAWING(S)

Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:

FIG. 1 is an isometric view of a friction pull plug in accordance with an embodiment of the present invention; and
FIG. 2 is a side view of the friction pull plug at its initial point of contact with the side walls of a hole to be plugged.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring now to the drawings and more particularly to FIG. 1, a friction pull plug (FPP) 10 in accordance with an embodiment of the present invention is shown and is referenced generally by numeral 10. As is well known in the art and as will be explained later below, FPP 10 will be rotated about its longitudinal axis 12 at very high speeds as FPP 10 is pulled along longitudinal axis 12 into a hole that is to be plug welded. As will be explained further below, FPP 10 includes lateral surface angles that reduce or eliminate chatter as FPP 10 contacts a hole to be plugged.

FPP 10 includes a lower region or shank 20, a middle region 30 of frustoconical sections coupled on the longitudinal end thereof to one end of shank 20, and a top region 40 coupled on one end thereof to the opposing longitudinal end of region 30. Top region 40 includes a region 42 forming the uppermost portion of a weld and a region 44 forming the portion of FPP 10 that is not drawn into a material’s hole to be plugged. However, top region 40 does not form part of the present invention and will not be discussed further herein.

As mentioned above, all three regions 20, 30 and 40 share a common longitudinal axis 12. Regions 20, 30 and 40 can be a one-piece integrated structure.

Lower region or shank 20 is generally a cylindrical element having a constant diameter illustrated and referenced hereinafter as diameter D1. As is known in the art, shank 20 is the portion of FPP 10 that is engaged by a portion of a tool/machine (not shown) that will rotate FPP 10 at high speeds during a friction pull plug welding process.

Middle region 30 defines a series of frustoconical sections aligned longitudinal axis 12. Briefly, middle region 30 is a series of three inverted frustoconical sections 32, 34 and 36 where the sections are inverted relative to shank 20. Frustoconical section 32 is adjacent to shank 20, frustoconical section 34 is adjacent to section 32, and frustoconical section 36 is adjacent to section 34. The smallest diameter of section 32 is referenced as D2, and the largest diameter of section 32 is referenced as D3. The smallest diameter section 34 is referenced as D2, and the largest diameter of section 34 is referenced as D3. Finally, the smallest diameter of section 36 is referenced as D2, and the largest diameter of section 36 is referenced as D3. The relationship between the various diameters will be explained later below.

The lateral surface angles of sections 34 and 36 allow FPP 10 to reduce or eliminate chatter during a friction pull plug weld process. Each of lateral surface angles A1 and A2 of
sections 34 and 36, respectively, is defined as the angle made between longitudinal axis 12 (indicated by dashed line 12' that is parallel to longitudinal axis 12) and the lateral surfaces 34A and 36A of sections 34 and 36, respectively. As will be explained further below, lateral surface 34A serves as the initial contact with a material’s hole as FPP 10 is drawn therein, and lateral surface 36A serves as a major portion of the weld region of FPP 10 with the sides of the material’s hole. In general, lateral surface angle A₁ is an angle between approximately 7.5° and approximately 22.5°. Lateral surface angle A₂ is an angle that is less than angle A₁ and is between approximately 5° and approximately 7.5°. In tests of the present invention for material thicknesses on the order of 0.5 inches to 0.625 inches, and plug rotation speeds on the order of 5000 to 6500 RPM, no chatter resulted when angle A₁ was approximately 20° and angle A₂ was approximately 6.5°. Changes in angles A₁ and A₂ can be affected by materials used, stroke rates, material thickness, plug rotation speeds, etc.

Referring additionally now to FIG. 2, a side view of FPP 10 is illustrated where horizontal dashed lines have been added to facilitate delineation between the various sections of FPP 10. In accordance with the present invention, lateral surface 34A of FPP 10 first makes contact with a hole 102 in a material 100 at points on lateral surface 34A. That is, FPP 10 at its initial contact point between hole 102 and lateral surface 34A defines a diameter that is between D₂ (or the smallest diameter of section 34) and D₃ (or the largest diameter of section 34). Hole 102 has a diameter D. The various diameter relationships for FPP 10 are as follows:

\[ D₁ < D \]
\[ D₂ < D \]
\[ D₃ > D₂ \text{ and } D₃ > D₄ \]
\[ D₄ > D₃ \]
\[ D₅ > D₄ \]
\[ D₆ > D₅ \]

In accordance with these relationships, the initial contact point of FPP 10 with hole 102 occurs along lateral surface 34A having lateral surface angle A₃ as described above.

The advantages of the present invention are numerous. The friction pull plug of the present invention reduces or eliminates chatter during a friction pull plug welding process. The plug as described herein is suitable for use in thin and thicker materials. By reducing or eliminating chatter, the ultimate weld region will be consistent as the plug is properly seated during the weld process.

Although the invention has been described relative to a specific embodiment thereof, there are numerous variations and modifications that will be readily apparent to those skilled in the art in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A friction pull plug and material configuration for an anti-chatter friction pull plug weld, comprising:
   - a material having a hole wherein said hole has a diameter D₁ and
   - a friction pull plug including a shank having a constant diameter D₄ wherein D₄ < D,
   - a first inverted frustoconical section coupled directly to said shank, said first inverted frustoconical section having a smallest diameter D₂ wherein D₂ < D, said first inverted frustoconical section having a largest diameter D₃ wherein D₃ > D, and
   - a second inverted frustoconical section coupled directly to said first inverted frustoconical section, said second inverted frustoconical section having a smallest diameter D₄ wherein D₄ < D, said second inverted frustoconical section having a largest diameter D₅ wherein D₅ > D, said second inverted frustoconical section having a longitudinal axis and a first lateral surface wherein a first angle defined between said longitudinal axis and said first lateral surface is between approximately 7.5° and approximately 22.5°; and
   - a third inverted frustoconical section coupled directly to said second inverted frustoconical section, said third inverted frustoconical section having a smallest diameter D₆ wherein D₆ < D, said third inverted frustoconical section having a largest diameter D₇ wherein D₇ > D, said third inverted frustoconical section having a shank having a constant diameter D₈ wherein D₈ < D,
   - a first inverted frustoconical section coupled directly to said shank, said first inverted frustoconical section having a smallest diameter D₉ wherein D₉ < D, said first inverted frustoconical section having a largest diameter D₁₀ wherein D₁₀ > D, said first inverted frustoconical section having a longitudinal axis and a first lateral surface wherein a first angle defined between said longitudinal axis and said first lateral surface is between approximately 7.5° and approximately 22.5°; and
   - a third inverted frustoconical section coupled directly to said second inverted frustoconical section, said third inverted frustoconical section having a smallest diameter D₁₁ wherein D₁₁ < D, said third inverted frustoconical section having a largest diameter D₁₂ wherein D₁₂ > D, said third inverted frustoconical section having a shank having a constant diameter D₁₃ wherein D₁₃ < D,
   - a first inverted frustoconical section coupled directly to said shank, said first inverted frustoconical section having a smallest diameter D₁₄ wherein D₁₄ < D, said first inverted frustoconical section having a largest diameter D₁₅ wherein D₁₅ > D, said first inverted frustoconical section having a longitudinal axis and a first lateral surface wherein a first angle defined between said longitudinal axis and said first lateral surface is between approximately 7.5° and approximately 22.5°; and
   - a third inverted frustoconical section coupled directly to said second inverted frustoconical section, said third inverted frustoconical section having a smallest diameter D₁₆ wherein D₁₆ < D, said third inverted frustoconical section having a largest diameter D₁₇ wherein D₁₇ > D, said third inverted frustoconical section having a shank having a constant diameter D₁₈ wherein D₁₈ < D,
   - a first inverted frustoconical section coupled directly to said shank, said first inverted frustoconical section having a smallest diameter D₁₉ wherein D₁₉ < D, said first inverted frustoconical section having a largest diameter D₂₀ wherein D₂₀ > D, said first inverted frustoconical section having a longitudinal axis and a first lateral surface wherein a first angle defined between said longitudinal axis and said first lateral surface is between approximately 7.5° and approximately 22.5°; and
   - a third inverted frustoconical section coupled directly to said second inverted frustoconical section, said third inverted frustoconical section having a smallest diameter D₂₁ wherein D₂₁ < D, said third inverted frustoconical section having a largest diameter D₂₂ wherein D₂₂ > D, said third inverted frustoconical section having a shank having a constant diameter D₂₃ wherein D₂₃ < D,
   - a first inverted frustoconical section coupled directly to said shank, said first inverted frustoconical section having a smallest diameter D₂₄ wherein D₂₄ < D, said first inverted frustoconical section having a largest diameter D₂₅ wherein D₂₅ > D, said first inverted frustoconical section having a longitudinal axis and a first lateral surface wherein a first angle defined between said longitudinal axis and said first lateral surface is between approximately 7.5° and approximately 22.5°; and
   - a third inverted frustoconical section coupled directly to said second inverted frustoconical section, said third inverted frustoconical section having a smallest diameter D₂₆ wherein D₂₆ < D, said third inverted frustoconical section having a largest diameter D₂₇ wherein D₂₇ > D, said third inverted frustoconical section having a shank having a constant diameter D₂₈ wherein D₂₈ < D,
   - a first inverted frustoconical section coupled directly to said shank, said first inverted frustoconical section having a smallest diameter D₂₉ wherein D₂₉ < D, said first inverted frustoconical section having a largest diameter D₃₀ wherein D₃₀ > D, said first inverted frustoconical section having a longitudinal axis and a first lateral surface wherein a first angle defined between said longitudinal axis and said first lateral surface is between approximately 7.5° and approximately 22.5°; and
   - a third inverted frustoconical section coupled directly to said second inverted frustoconical section, said third inverted frustoconical section having a smallest diameter D₃₁ wherein D₃₁ < D, said third inverted frustoconical section having a largest diameter D₃₂ wherein D₃₂ > D, said third inverted frustoconical section having a shank having a constant diameter D₃₃ wherein D₃₃ < D,
   - a first inverted frustoconical section coupled directly to said shank, said first inverted frustoconical section having a smallest diameter D₃₄ wherein D₃₄ < D, said first inverted frustoconical section having a largest diameter D₃₅ wherein D₃₅ > D, said first inverted frustoconical section having a longitudinal axis and a first lateral surface wherein a first angle defined between said longitudinal axis and said first lateral surface is between approximately 7.5° and approximately 22.5°; and
   - a third inverted frustoconical section coupled directly to said second inverted frustoconical section, said third inverted frustoconical section having a smallest diameter D₃₆ wherein D₃₆ < D, said third inverted frustoconical section having a largest diameter D₃₇ wherein D₃₇ > D, said third inverted frustoconical section having a shank having a constant diameter D₃₈ wherein D₃₈ < D,
   - a first inverted frustoconical section coupled directly to said shank, said first inverted frustoconical section having a smallest diameter D₃₉ wherein D₃₉ < D, said first inverted frustoconical section having a largest diameter D₄₀ wherein D₄₀ > D, said first inverted frustoconical section having a longitudinal axis and a first lateral surface wherein a first angle defined between said longitudinal axis and said first lateral surface is between approximately 7.5° and approximately 22.5°; and
   - a third inverted frustoconical section coupled directly to said second inverted frustoconical section, said third inverted frustoconical section having a smallest diameter D₄₁ wherein D₄₁ < D, said third inverted frustoconical section having a largest diameter D₄₂ wherein D₄₂ > D, said third inverted frustoconical section having a shank having a constant diameter D₄₃ wherein D₄₃ < D,
   - a first inverted frustoconical section coupled directly to said shank, said first inverted frustoconical section having a smallest diameter D₄₄ wherein D₄₄ < D, said first inverted frustoconical section having a largest diameter D₄₅ wherein D₄₅ > D, said first inverted frustoconical section having a longitudinal axis and a first lateral surface wherein a first angle defined between said longitudinal axis and said first lateral surface is between approximately 7.5° and approximately 22.5°; and
   - a third inverted frustoconical section coupled directly to said second inverted frustoconical section, said third inverted frustoconical section having a smallest diameter D₄₆ wherein D₄₆ < D, said third inverted frustoconical section having a largest diameter D₄₇ wherein D₄₇ > D, said third inverted frustoconical section having a shank having a constant diameter D₄₈ wherein D₄₈ < D,
   - a first inverted frustoconical section coupled directly to said shank, said first inverted frustoconical section having a smallest diameter D₄₉ wherein D₄₉ < D, said first inverted frustoconical section having a largest diameter D₅₀ wherein D₅₀ > D, said first inverted frustoconical section having a longitudinal axis and a first lateral surface wherein a first angle defined between said longitudinal axis and said first lateral surface is between approximately 7.5° and approximately 22.5°; and
dinal axis and said second lateral surface is less than said first angle and is between approximately 5° and approximately 7.5°,

wherein, when said one-piece plug structure is positioned with said first frustoconical section and a portion of said second frustoconical section in said hole, said first lateral surface area contacts said material at said hole.

4. A friction pull plug and material configuration as in claim 3, wherein said first angle is approximately 20° and wherein said second angle is approximately 6.5°.

5. A friction pull plug and material configuration for an anti-chatter friction pull plug weld, comprising:
   a material having a hole therein wherein said hole has a diameter D;
   a one-piece plug structure including a cylindrical shank and a series of three frustoconical sections wherein a common longitudinal axis extends through said cylindrical shank and said series of three frustoconical sections;
   said shank having a constant diameter D, wherein D1 < D;
   said series of three frustoconical sections having a first frustoconical section directly adjacent to said cylindrical shank, a second frustoconical section directly adjacent to said first frustoconical section, and a third frustoconical section directly adjacent to said second frustoconical section;
   said first frustoconical section having a smallest diameter D2 adjacent to said cylindrical shank wherein D2 < D,
   said first frustoconical section having a largest diameter D3 wherein D3 > D2 and D3 < D;
   said second frustoconical section having a smallest diameter D4 adjacent to said first frustoconical section wherein D4 = D3, said second frustoconical section having a largest diameter D5 wherein D5 > D4, said second frustoconical section having a first lateral surface wherein a first angle defined between said longitudinal axis and said first lateral surface is between approximately 7.5° and approximately 22.5°; and
   said third frustoconical section having a smallest diameter D6 adjacent to said second frustoconical section wherein D6 = D5, said third frustoconical section having a largest diameter D7 wherein D7 > D6, said third frustoconical section having a second lateral surface wherein a second angle defined between said longitudinal axis and said second lateral surface is less than said first angle and is between approximately 5° and approximately 7.5°,

wherein, when said one-piece plug structure is positioned with said first frustoconical section and a portion of said second frustoconical section in said hole, said first lateral surface area contacts said material at said hole.

6. A friction pull plug and material configuration as in claim 5, wherein said first angle is approximately 20° and wherein said second angle is approximately 6.5°.

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