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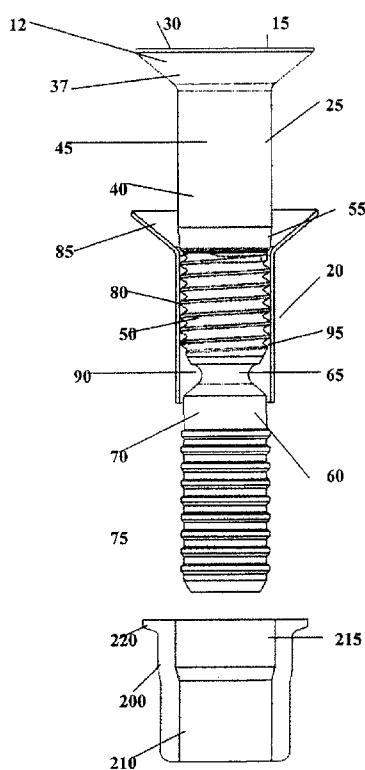
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(54) Title: HIGH PERFORMANCE SLEEVED INTERFERENCE FASTENERS FOR COMPOSITE APPLICATIONS



(57) Abstract: A fastener adapted to pass through aligned holes through workpieces is disclosed. The fastener includes a pin member having a transition portion wherein the diameter of the transition portion decreases radially as it extends from the smooth cylindrical shank portion to the threaded portion. The fastener may also comprise a sleeve member and a clamping means. The clamping means includes a collar, a nut, or any other possible clamping means. In exemplary embodiments, the workpieces can be formed with a plurality of materials, the materials including composite, metallic, or composite/metallic structures, any combination thereof. In particular embodiments, the fastener has interference capability of 0.0005 to 0.0100 inches in composite structures without risk of composite delamination or damage. As a result of the fastener interference, gaps between the fastener and the structure are eliminated thereby providing good electrical conductivity between components. As a result, the potential for electrical sparks is reduced, providing a safer fastener for use with aerospace applications.

HIGH PERFORMANCE SLEEVED INTERFERENCE FASTENERS FOR COMPOSITE APPLICATIONS

BACKGROUND

[0001] 1. *Field*

5 **[0002]** The present disclosure relates to an improved threaded fastener and method for securing workpieces of composite materials. In particular embodiments, the present disclosure relates to a fastener including a pin and a preformed sleeve which may be placed around the pin for use in interference applications.

10 **[0003]** 2. *General Background*

15 **[0004]** More and more graphite composite materials are being incorporated into aircraft structures. Use of graphite composites increase strength, increase life, reduce weight, reduce fuel consumption, increase payload, among other benefits. However, as these newer materials are utilized, new challenges need to be overcome in fastening technology when compared to typical metallic structures.

20 **[0005]** Existing aerospace fasteners cannot be safely installed in interference conditions in graphite or mixed graphite-composite metallic structures. Typically, clearance fit fasteners are utilized to avoid concerns of composite delamination and potential structural failure that make these fasteners unsafe to utilize. As a result, fasteners are installed in clearance holes that result in the reduction of dynamic joint performance, gaps in the structure, and other structural concerns.

25 **[0006]** The resulting gap between the fastener shank portion and hole prevent uniform contact of structural components. Consequently, safe dissipation of lightning strike current/energy, and electro-magnetic currents is a major concern. Currently, aircraft manufacturers are resorting to elaborate, expensive, and sometimes risky alternative methods to properly ground the structure. For

example, copper, or another low conductive strip, may be incorporated onto the surface of the workpieces to provide a preferential low resistance path for any current. Additionally, a film adhesive containing a conductive fiber carrier film capable of conducting high currents between two workpieces may be utilized.

5 However, both of these methods are very expensive and not a cost effective way to provide safe dissipation of current.

[0007] Additionally, prior fasteners cannot be installed with significant amounts of sealant, as is required in most aircraft structures. If sufficient sealant is utilized during installation, the coefficient of friction between the fastener 10 assembly and the workpieces is reduced hindering installation capability. Additionally, there is an inability to flow any excess sealant out of the joint.

[0008] Further, previous pins with mating sleeves manufactured for interference applications are only capable of being installed in 100% graphite composite materials. In addition, these fasteners are limited to applications of 15 short lengths and small diameters. Prior fasteners cannot be installed in any composite/metallic structures and most 100% percent composite structures.

[0009] Additionally, previous fasteners for interference applications are only available in shear load range strength capabilities. The collars utilized in these fasteners are typically commercially pure titanium and subject to creep at fairly 20 low elevated temperatures.

[0010] Thus, there is a need to provide a fastener that allows for interference applications without the possibility of delamination and structural failure.

[0011] There is also a need to provide a fastener that may be used in a variety of different applications. Utilization of a fastener in a variety of 25 composite/metallic structures is needed.

[0012] Additionally, there is a need to provide fasteners which provide safe dissipation of electrical currents caused by lightning strikes and/or static electricity. Fasteners that allow for uniform contact of the structural components

will provide the necessary dissipation and a safer, more cost effective solution to the problems involving electrical currents.

SUMMARY

[0013] In one aspect of the present disclosure, a fastener is disclosed having a 5 pin. The pin member includes an elongated smooth cylindrical shank portion and an enlarged head for mating with the sleeve. In some embodiments, there is a countersink or protruding head for engagement with a flared end of the sleeve. The pin member also includes a threaded portion and a frangible portion axially aligned with the smooth cylindrical shank portion. The frangible portion 10 includes a pull groove portion having circumferential pull grooves adapted to be gripped for applying a relative axial force to pull the pin member into the sleeve. The pin member includes a breakneck groove between the threaded portion and the frangible portion. As the fastener is installed, the frangible portion is separated at the breakneck groove.

15 **[0014]** The pin includes a transition portion between the smooth cylindrical shank portion and the threaded portion designed and optimized to minimize the installation force required for the high interference conditions resulting from installation. In exemplary embodiments, the transition portion may be tapered and have an angle less than or equal to 20 degrees from the pin shank. In other 20 embodiments, the transition portion reduces the radial diameter of the pin shank between 0.004 to about 0.005 inches over a distance of 0.010 to 0.290 inches between the smooth portion and the threaded portion.

[0015] In other embodiments, the fastener further comprises a sleeve and a clamping means to secure together workpieces. The clamping means may 25 comprise a collar or nut member or any other means suitable to fasten the workpieces together with the pin and sleeve. The fastener is installed through aligned holes located in two or more workpieces. In some embodiments, one of the holes through the workpieces includes a countersink, or lead in radius, on its outer opening.

[0016] The sleeve, adapted to fit over the smooth cylindrical shank portion, includes a tubular portion and an enlarged end for engagement with the outer surface of the workpiece. In some embodiments, there is a flared end for engagement with the countersink portion in the workpieces. The sleeve has a 5 length greater than the maximum total thickness of the workpieces to be joined at the location of the aligned holes. The tubular portion of the sleeve has an inner diameter less than the diameter of the smooth cylindrical shank portion and an outer diameter sized to permit fitting of the sleeve into the aligned clearance holes of the workpieces.

10 **[0017]** In one aspect, the pin member has a smooth cylindrical shank portion with a diameter greater than the maximum inner diameter of the sleeve. When the smooth cylindrical shank portion enters into and pulls through the sleeve, the sleeve radially expands into an interference fit with the walls of the holes of the workpieces.

15 **[0018]** The tubular collar member is adapted to be fit over the threaded portion of the pin member including a counterbore to enable the collar to provide clearance over the sleeve, and an annular flange portion at one end for engagement with the other outer surface of the workpieces. The collar member includes an enlarged cylindrical shank portion having a uniform outside diameter 20 adapted to be swaged into the threaded portion of the pin.

[0019] In another embodiment, the nut member is adapted to fit the threaded portion of the pin member including a counterbore to enable the nut member to provide clearance over the sleeve, and an annular flange portion at one end for engagement with the other outer surface of the workpieces. The nut member 25 includes a threaded portion to be threaded onto the threaded portion of the pin to secure the fastener to the workpieces.

[0020] In another aspect, the sleeve member includes lubrication on the inner diameter surface to reduce friction as the pin smooth cylindrical shank portion enters the sleeve. The outer diameter surface of the sleeve and/or the inner

diameter of the aligned holes has a rougher surface. In particular embodiments, the coefficient of friction between the inner surface of the sleeve and the smooth cylindrical shank portion of the pin member is less than the coefficient of friction between the outer surface of the sleeve and inner diameter of the holes, allowing 5 the sleeve to expand radially upon insertion of the smooth cylindrical shank portion of the pin member to be in an interference fit.

10 **[0021]** In a further aspect, a fastener is disclosed that has the capability of being installed in composite, metallic, or composite/metallic structures. For example, the disclosed fastener could be installed in, for example, graphite composites, titanium, aluminum, or a mixture of these components.

[0022] In another aspect, as a result of the fastener interference, gaps between the fastener and the structure are eliminated thereby providing good electrical conductivity between components. As a result, the potential for electrical sparks is reduced, providing a safer fastener for use with aerospace applications.

15 **[0023]** In another aspect, the fastener has interference capability of 0.0005 to 0.0100 inches in composite and/or metallic structures without risk of composite delamination or damage.

[0024] In an additional aspect of the present disclosure, the fastener has a functional grip capability of about 0.062 to about 0.140 inches.

20 **[0025]** Other objects, features, and advantages of the present disclosure will become apparent from the subsequent description and the appended claims, taken in conjunction with the accompanying drawings

DRAWINGS

[0026] The foregoing aspects and advantages of present disclosure will 25 become more readily apparent and understood with reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

[0027] FIG. 1 illustrates an exemplary embodiment of the fastener showing the pin and the sleeve of the fastener, the pin having an enlarged flush head.

[0028] FIG. 2 illustrates another exemplary of the fastener showing the pin and the sleeve of the fastener, the pin having an enlarged protruding head

5 **[0029]** FIG. 3 illustrates another embodiment of the fastener showing the pin and sleeve of the fastener, the pin having a longer threaded area and no frangible portion and an enlarged flush head.

[0030] FIG. 4 illustrates another embodiment of the fastener showing the pin and sleeve of the fastener, the pin having an enlarged protruding head.

10 **[0031]** FIG. 5 illustrates a plurality of workpieces having aligned holes for installation of the fastener to secure the workpieces together.

[0032] FIG. 6 illustrates a plurality of workpieces having aligned holes for installation of the fastener to secure the workpieces together, the outer portion of one of the workpieces having a countersink.

15 **[0033]** FIG. 7 illustrates the exemplary fastener before the pin has been pushed or pulled through the sleeve. The sleeve has not expanded and stretched to a desired interference fit.

[0034] FIG. 8 illustrates the fastener after the pin has been pushed or pulled into position and also illustrates the collar placed onto the pin prior to swaging.

20 **[0035]** FIG. 9 illustrates the fastener with the collar swaged onto the threaded portion of the pin to secure the fastener prior to pintail separation.

[0036] FIG. 10 illustrates the fastener in an engaged, installed position, after pintail separation.

DETAILED DESCRIPTION

25 **[0037]** A fastener for securing together a plurality of workpieces 105, 110 and adapted to be located in aligned holes 125, 130 in such workpieces is disclosed. In exemplary embodiments, the fastener 10 includes a pin member 15, a sleeve

member 20 and a collar 200. In other embodiments, the fastener may include a nut instead of a collar. In exemplary embodiments, the workpieces 105, 110 can be formed with a plurality of materials, the materials including composite, metallic, or composite/metallic structures, or any combination thereof. In 5 particular embodiments, the workpieces 105, 110 may be constructed from titanium, aluminum, graphite composites, or any combination thereof.

[0038] An embodiment of the pin and sleeve assembly 12 is shown in FIG. 1 and 2. The pin member 15 includes an elongated shank portion 40 which terminates at one end 30 with an enlarged flush head 37 or protruding head 35. 10 The pin shank portion 40 includes a substantially smooth cylindrical portion 45, a threaded portion 50, and a frangible portion 60. The smooth cylindrical shank portion extends from the head 35, 37 and is adapted to be received by the expansion sleeve 20. Following the substantially smooth cylindrical portion 45 is a threaded portion 50. The threaded portion 50 is generally uniformly threaded 15 throughout its length. A tapered transition portion 55 smoothly merges the threaded portion 50 with the smooth cylindrical shank portion 45.

[0039] The frangible portion 60 of the pin member 15 extends from the threaded portion 50. The frangible portion 60 includes a cylindrical land 70 and a pull groove portion 75 having circumferential pull grooves 75. A breakneck 20 groove 65 that is located adjacent to the threaded portion 50 and defines the weakest portion of the fastener 10.

[0040] In some embodiments, the threaded portion 50, breakneck groove 65, straight land 70 and pull groove portion 75 has a maximum diameter which is less than the diameter of the smooth cylindrical portion 45 of the shank portion, 25 the straight land portion 70 having a diameter smaller than that of the threaded portion 50 and pull groove portion 75.

[0041] In this embodiment, the expansion sleeve member 20 has a generally uniform tubular portion 80 that terminates in an enlarged flanged shaped head 85 to receive the flush head 37 or protruding head 35 of the pin member 15. The

sleeve **20** has an internal diameter that is greater than the threaded portion **50** and frangible portions **60** of the pin **15**, but less than the diameter of the smooth cylindrical shank portion **45**.

[0042] The inner diameter of the sleeve member **20** includes a low friction coating on its surface **90** to facilitate movement of the pin member **15** into the sleeve **20** during installation. In a particular embodiment, the sleeve member **20** is coated with low friction coating to eliminate the resistance between the smooth cylindrical shank portion **45** of the pin member **15** and the inner diameter surface **90** of the sleeve tubular portion **80**. The low friction coating on the inner diameter of the sleeve allows the pin member **15** to slide through the sleeve member **20** easier due to reduced frictional loading.

[0043] Additionally, the coating on the inside diameter surface **90** enables the installation of the fastener to function when fasteners are installed with minimum, moderate, or heavy amounts of sealant on the fastener and in the installed joint.

[0044] Another embodiment of the fastener is illustrated in Fig. 3 and Fig. 4. In this embodiment, the pin member **15** includes an elongated shank portion **40** which terminates at one end **30** with an enlarged head **35, 37**. This embodiment may also have a protruding head **37** as shown in the embodiment in Figure 2. The pin shank portion **40** includes a substantially smooth cylindrical portion **45**, a threaded portion **50**, but does not include a frangible portion. The smooth cylindrical shank portion extends from the head **35, 37** and is adapted to be received by the expansion sleeve **20**. Following the substantially smooth cylindrical portion **45** is a threaded portion **50**. The threaded portion **50** is generally uniformly threaded throughout its length. A tapered transition portion **55** smoothly merges the threaded portion **50** with the smooth cylindrical shank portion **45**.

[0045] The workpieces **105, 110** have aligned holes **125, 130** is shown in Fig. 5 and 6. The fastener assembly **10** extends through the aligned holes **125, 130** to secure the workpieces **105, 110**. The outer surface of the workpieces **115**

receive the enlarged head of the sleeve. As seen in the embodiment depicted in Figure 6, the opening in the outer workpiece **105** terminates at its outer surface **115** in a countersink portion **120**, or lead in radius portion, which is shaped to receive the enlarged flange **85** of the expansion sleeve member **20**.

5 [0046] The outer diameter of the sleeve tubular portion **80** before the pin member **15** is pushed or pulled into the sleeve member **20** is smaller than the diameter of the holes placed in the workpieces **105, 110**. Accordingly, there is a space between the outer diameter of the sleeve and the inner diameter of the holes as shown in Fig. 7. The outside diameter of the sleeve tubular portion **80**,
10 in its pre-expanded state, and the diameter of the bores provide a slip fit when the tubular portion of the sleeve member **20** is located within the holes.

[0047] During installation, as the pin member **15** is pushed or pulled through the sleeve, the sleeve expands radially to a desired interference fit with the walls of the holes **125, 130** through workpieces **105, 110** as the pin shank portion is
15 inserted into the sleeve member **20** as depicted in FIG. 8. In this manner, the sleeve member **20** is shielding the surfaces of the clearance holes from the pin shank portion, and thus, eliminating delamination of the plurality of workpieces as the pin is pushed or pulled into the sleeve member **20**.

[0048] The tapered transition portion **55** is designed and optimized to minimize
20 the installation force required for the high interference conditions resulting from the pin member **15** installation into the sleeve member **20**. The transition portion **55** has a shallow lead-in angle that reduces the force that is needed for installation. Since less force is needed to install the fastener **10** into the interference condition, the fastener **10** allows for much longer grip lengths while
25 diminishing sleeve stretch and premature sleeve failure.

[0049] In exemplary embodiments, the transition portion **55** may be tapered and have an angle of less than or equal to 20 degrees from the pin shank as the diameter decreases radially from the smooth shank portion to the thread portion. In the embodiment illustrated, the diameter of the transition portion **55** is tapered

and decreases in a uniform fashion. However, the transition portion can be any shape as long as the radius of the pin shank decreases. For example, the transition portion could be a gentle radius decrease shaped as a convex curve, a concave curve or an s-shaped curve, or be in configuration that would allow a 5 reduction in the radius between the smooth shank portion and the threaded portion of the pin. In these embodiments, the transition portion **55** reduces the radius of the pin shank between 0.004 to about 0.005 inches over a distance of 0.010 to 0.290 inches. In exemplary embodiments, the sleeve **20** radially expands between about 0.003 and 0.012 inches as the fastener is installed. In 10 an exemplary embodiment, the interference of the fastener **10** with the workpieces **105, 110** is about 0.0005 to 0.0100 inches.

[0050] As a result of the fastener interference of the disclosed fastener **10**, gaps between the fastener **10** and the workpiece structures are eliminated. Accordingly, good electrical conductivity between the components is provided. 15 The potential for electrical sparks is reduced making the fastener **10** more safe for use in aerospace applications.

[0051] In exemplary embodiments, the surface of the outer diameter of the sleeve **20** and/or the inner diameter of the holes **125, 130** is rougher or coarser. By providing a rougher surface on these two areas, the coefficient of friction 20 between the outer surface **95** of the sleeve member **20** and the inside diameter surface **135** of the holes **125, 130** is increased. Essentially the coefficient of friction and/or the force of pushing or pulling the pin **15** into the sleeve member **20** must be lower than the coefficient of friction and/or the load between the sleeve outer diameter surface **95** and the inner diameter surface **135** of the holes 25 to provide the radial expansion of the tubular portion **80** of the sleeve **20**. Without the differential coefficient of friction, the sleeve **20** may be pulled into the holes prior to installation.

[0052] In exemplary embodiments, the rougher outer surface of the sleeve and/or the inner surface of the holes combined with the lubrication on the inner 30 surface **90** of the sleeve member **20** prevents the excessive stretching of the

sleeve **20** during installation. The coefficient of friction between the outer surface **95** of the sleeve and inner surface **135** of the holes is greater than the coefficient of friction between the inner surface of the sleeve and the smooth cylindrical shank of the pin member. As a result, the sleeve **20** expands radially 5 into the interference position and the stretching of the sleeve **20** is diminished.

[0053] In exemplary applications, the difference in the coefficient of friction will allow the stretching of the sleeve member **20** to be reduced to less than 0.050 inches. Additionally, the characteristics of the surfaces of the sleeve **20** allow for the use of sealant in the joint and on the fastener **10**.

10 **[0054]** In exemplary embodiments, the optimized angled transition portion geometry **55** of the pin member **15** is designed to minimize the installation force necessary to install the fastener **10** into the interference conditions up to 0.010 inches. The geometry designed allows the force applied when inserting the pin to be applied perpendicular to the angled transition portion **55**, instead of parallel 15 to the insertion of the pin member **15** as with traditional bull-nose transition geometry. A lower force is needed to insert the pin member **15**. As a result of the lower force required, the fastener **10** can be installed with a larger variety of workpieces, including metallic, composite and metallic/composite structures.

[0055] The transition geometry, the tapered transition portion **55**, on the pin 20 member **15** is also important as it allows functionality with much longer grip lengths without excessive sleeve stretch and/or premature sleeve failure.

[0056] To fully clamp the workpieces together, a clamping means is utilized. The clamping means could be either the threaded nut member **250** depicted in Figure 3 or the collar member **200** illustrated in Figure 8. Other clamping means 25 may also be utilized to secure the workpieces together.

[0057] In one embodiment, a symmetrically shaped, tubular collar **200** of a pre-selected material is placed over the installed pin and sleeve assembly **12** as illustrated in FIG. 8. As the workpieces **105, 110** are secured together, the collar will be in radial alignment with the threaded portion of the pin member **15**. The

collar **200** has a counterbore portion **215** that is adapted to be located over the pin shank and a collar through bore, the inner diameter of the through bore **210** being selected to provide clearance to the pull grooves **75** and threaded portion **50** of the pin **15**. The collar geometry is volume balanced. Significantly, the wall 5 thickness of the collar **200** is uniform and symmetrically shaped for swaging into the threaded portion **50** to provide the desired clamp load.

[0058] As illustrated in FIG. 3, another embodiment of the fastener **10** utilizes a nut member **250** to secure the workpieces together. The nut member **250** includes a threaded portion **255** to mate with the threaded portion **50** of the pin 10 member.

[0059] Both the collar member **200** or nut member **250** has a counterbore portion **215** at one end that allows the collar **200** or nut **250** to clear the sleeve component **20**. Thus, the counterbore portion **215** has a diameter greater than the outer diameter of the sleeve **20**. As a result, the installed fastener **10** has a 15 reduced height and weight. This makes the fastener **10** a much more cost-effective solution than previous fasteners.

[0060] Both the collar **200** or nut member **250** also include an enlarged flange **220** at one end. The flange **220**, being in engagement with the outer surfaces **140** of the plurality of workpieces, is provided to have a predetermined area of 20 engagement in order to distribute the installation and final clamp loads on the outer surfaces **140** of the workpieces **105, 110**. When the workpieces **105, 110** include at least one composite material, the engagement area of the flange **220** is selected to be sufficient to resist localized delamination or crushing of the composite material at the outer surfaces of the workpieces **105, 110**.

25 **[0061]** The collar member of the fastener **10** is swaged to the threaded portion of the pin member **15** as shown in FIG. 9. In particular embodiments, the optimized collar geometry balanced with the existing thread forms and installation tools to allow swaging of the collar into the threaded portion **50**. The collar **200** may be swaged into about 40 to 60% of the depth of the threads **50**

while maintaining control of the collar material and achieving a consistent high, clamp load/preload.

[0062] A consistent, high fastener **10** clamp significantly increases the dynamic joint performance and life of the aircraft structure. In particular embodiments, the 5 high clamp/preload averages about 50 to 96% of the minimum tensile strength of the installed fastener. In more exemplary embodiments, the high clamp/preload averages about 78% of the minimum tensile strength. In typical fasteners, the high clamp/preload averages only about 50% of the minimum tensile strength.

[0063] Additionally, the controlled, partial fill of the threaded portion **50** of the 10 pin member **15** allows for significant and even sealant flowout during installation. The mechanical performance of the fastener **10** is not reduced with this sealant flowout.

[0064] The controlled, swaged fill by the collar **200** is also an improvement compared to prior art fasteners. In typical applications, there is an inherent gap 15 between the internal and external threads of the pin member and the collar or nut. In addition, the non-pressure side of the fastener **10** and the counterbores of the collar or nut has gaps between the components. The fastener **10** disclosed herein creates full contact on both sides of the threaded portion **50** of the pin **15**, eliminating gaps. Accordingly, the fastener has better conductivity 20 and provides a safer fastener for aerospace conditions, in addition to improving fuel tightness.

[0065] When the collar **200** is swaged, it is swaged over the end portion of the sleeve member **20**. As a result, the sleeve member **20** is compressed over the transition angle portion **55** of the pin **15**. Accordingly, the sleeve **20** and pin **15** 25 can then be removed as a single unit if necessary. This improves the efficiency and workability of the fastener **10** installed in various applications while also improving conductivity.

[0066] An exemplary implementation of the installed fastener **10** is illustrated in FIG. 9. The fastener **10**, with the pin having a shank of predetermined length

can be selected to fasten the plurality of workpieces **105, 110** having a grip varying in total thickness from a minimum to a maximum total thickness. Since it is desirable to have the sleeve encompass the entire grip length, the sleeve is predetermined to have a length no less than the maximum total width of the 5 plurality of workpieces **105, 110**.

[0067] For particular applications of the disclosed fastener, 110% of minimum mechanical performance is achieved with a functional grip capability of about 0.136 inches. Typical fasteners only have a functional grip capability of about 0.062 inches. Having a longer functional grip capability variance provides the 10 fastener **10** with more versatility to be used with different applications.

[0068] To install the fastener **10**, the sleeve is placed onto the pin as is depicted in FIG. 1. The sleeve **20** and pin **15** is then placed into the aligned holes of the workpieces **105, 110** so that a sufficient length of the frangible portion of the pin **15** extends beyond the outer surface of the plurality of 15 workpieces **105, 110** such that the tool can grip the pull grooves **75** of the pin member **15** for pull-in capability.

[0069] As the pin member **15** is pulled by the tool, the smooth cylindrical shank portion **45** of the pin member **15** will be pulled into the sleeve member **20** causing the sleeve **20** to expand radially outward. The magnitude of this 20 expansion is a function of the friction and force required between the smooth cylindrical shank pin portion **45** and the inner diameter surface **90** of the sleeve and the friction and force between the outer diameter of the sleeve **95** and the inner diameter of the holes **135** in the plurality of workpieces **105, 110**.

[0070] Then the collar member **200** is placed over the pin member **15** and 25 sleeve **20** so that the flange portion **220** sits against the workpiece surface **140**. At this point, a swaging tool is utilized to swage the collar member **200** onto the threaded portion **50** of the pin member, locking the fastener **10** into place.

[0071] In another embodiment, to install the fastener **10**, the sleeve is placed onto the pin as is depicted in FIG. 3. The sleeve **20** and pin **15** is then placed

into the aligned holes of the workpieces **105, 110**. The pin **15** is pushed into the sleeve **20** so that a sufficient length of the threaded portion of the pin **15** extends beyond the outer surface of the plurality of workpieces **105, 110** such that the threaded portion of the nut **250** can mate with the threaded portion of the pin.

- 5 The nut **250** is then installed and tightened to finalize the installation.

[0072] Thus, a unique fastener **10** is disclosed providing an interference fit within composite, metallic, and metallic/composite structures. The fastener **10** provides an improved dynamic joint performance as a result of better fastener interference and higher clamp loads. The geometry of the various components

- 10 allows for the interference conditions while eliminating delamination and potential structural failure. The interference eliminates gaps between the fastener **10** and the structure, providing good electrical conductivity and reducing the potential for electrical sparks, increasing the safety of the structure **10**.

[0073] While the above description contains many particulars, these should not

- 15 be considered limitations on the scope of the disclosure, but rather a demonstration of embodiments thereof. The fastener and uses disclosed herein include any combination of the different species or embodiments disclosed. Accordingly, it is not intended that the scope of the disclosure in any way be limited by the above description. The various elements of the claims and claims
- 20 themselves may be combined any combination, in accordance with the teachings of the present disclosure, which includes the claims.

CLAIMS

1. A fastener adapted to be located in holes through two or more workpieces, the fastener comprising:

5 a pin member having an enlarged pin head, a smooth cylindrical shank portion having an outer diameter, a tapered transition portion merging the smooth cylindrical shank portion with a threaded portion, the tapered transition portion being at an angle less than or equal to 20 degrees.

2. The fastener of claim 1 further comprising:

10 a sleeve adapted to fit over the smooth cylindrical shank portion, the sleeve having a length greater than or equal to a depth of the aligned holes, the sleeve having an enlarged head at one end, and a tubular portion having an inner diameter less than the outer diameter of the smooth cylindrical shank portion of the pin member and an outer diameter less than the diameter of the 15 aligned holes; and

wherein the sleeve expands radially upon insertion of the smooth cylindrical shank portion of the pin member into the aligned holes and the breakneck groove has an axial strength at least equal to the maximum axial load required to pull said pin member fully into the aligned holes, the smooth 20 cylindrical shank portion expanding the sleeve into an interference fit with the workpieces.

3. The fastener of claim 2 wherein the coefficient of friction between the inner surface of the sleeve and the smooth cylindrical shank portion of the pin member is less than the coefficient of friction between the outer surface of 25 the sleeve and inner diameter of the holes to reduce the amount of stretch of the sleeve allowing the smooth cylindrical shank portion to expand the sleeve into an interference fit with the workpieces of about 0.0005 to 0.0100 inches

4. The fastener of claim 1 further comprising a tubular collar member adapted to fit over the threaded portion, the collar member having an annular flange portion at one end, a collar shank portion adapted to be swaged into the threaded portion of the pin, and an enlarged counterbore between the flange portion and the collar shank portion, the counterbore having an inner diameter greater than the outer diameter of the sleeve; and

the pin member having a frangible portion having circumferential pull grooves, and a breakneck groove between the threaded portion and the frangible portion, the breakneck groove being the weakest portion of said pin member and adapted to fracture at a predetermined load; and

wherein the frangible portion can be severed from the pin shank at the breakneck groove after the collar member is swaged on the threaded portion.

5. The fastener of claim 3 further comprising a tubular nut member having an annular flange portion at one end, an threaded nut portion adapted to mate with the threaded portion of the pin, and an enlarged counterbore with an inner diameter greater than the outer diameter of the sleeve.

6. The fastener of claim 3 wherein the interference fit of the fastener with the plurality of workpieces is about 0.0005 to about 0.0100 inches after installation.

20 7. The fastener of claim 3 wherein the inner surface of the sleeve is coated with low friction coating to reduce the amount of friction as the smooth cylindrical shank portion of the pin enters the sleeve.

8. The fastener of claim 3 wherein the fastener has a high clamp preload of about 50 to 96 percent of a minimum tensile strength required for the 25 installed fastener.

9. The fastener of claim 3 wherein the fastener has a average preload of about 78% minimum tensile strength required for the installed fastener.

10. The fastener of claim 3 wherein the fastener has a grip range of about 0.136 inches and maintains about 110% of minimum mechanical performance.

11. The fastener of claim 3 wherein the fastener may be installed with 5 or without sealant.

12. The fastener of claim 3 wherein gaps between the fastener and the structure are eliminated providing good electrical conductivity.

13. The fastener of claim 3 that has a functional grip capability between the minimum and maximum thickness of the plurality of workpieces of 10 about 0.136 inches.

14. The fastener of claim 3 wherein the plurality of workpieces comprise graphite composites, titanium, aluminum, or a mixture of these components.

15. The fastener of claim 3 wherein the pin member has a protruding 15 head.

16. The fastener of claim 3 wherein the pin member has a flush head.

17. The fastener of claim 3 wherein the clearance between the collar and the threaded portion of the pin member allows sealant to escape during installation.

20 18. A fastener adapted to be located in holes through two or more workpieces, the fastener comprising:

25 a pin member having an enlarged pin head, a smooth cylindrical shank portion having an outer diameter, a transition portion merging the smooth cylindrical shank portion with a threaded portion, the transition portion having a length of between about 0.010 and .0290 inches, the diameter of the transition

portion decreasing radially between about 0.004 and 0.005 inches as it extends from the smooth cylindrical shank portion to the threaded portion.

19. The fastener of claim 18 further comprising:
 - a sleeve adapted to fit over the smooth cylindrical shank portion,
- 5 the sleeve having a length greater than or equal to a depth of the aligned holes, the sleeve having an enlarged head at one end, and a tubular portion having an inner diameter less than the outer diameter of the smooth cylindrical shank portion of the pin member and an outer diameter less than the diameter of the aligned holes; and
- 10 wherein the sleeve expands radially upon insertion of the smooth cylindrical shank portion of the pin member into the aligned holes and the breakneck groove has an axial strength at least equal to the maximum axial load required to pull said pin member fully into the aligned holes, the smooth cylindrical shank portion expanding the sleeve into an interference fit with the workpieces.
- 15

20. The fastener of claim 19 wherein the coefficient of friction between the inner surface of the sleeve and the smooth cylindrical shank portion of the pin member is less than the coefficient of friction between the outer surface of the sleeve and inner diameter of the holes to reduce the amount of stretch of the sleeve allowing the smooth cylindrical shank portion to expand the sleeve into an interference fit with the workpieces of about 0.0005 to 0.0100 inches
- 20

21. The fastener of claim 20 further comprising a tubular collar member adapted to fit over the threaded portion, the collar member having an annular flange portion at one end, a collar shank portion adapted to be swaged into the threaded portion of the pin, and an enlarged counterbore between the flange portion and the collar shank portion, the counterbore having an inner diameter greater than the outer diameter of the sleeve; and
- 25
- the pin member having a frangible portion having circumferential pull grooves, and a breakneck groove between the threaded portion and the

frangible portion, the breakneck groove being the weakest portion of said pin member and adapted to fracture at a predetermined load; and

wherein the frangible portion can be severed from the pin shank at the breakneck groove after the collar member is swaged on the threaded portion.

5 22. The fastener of claim 20 further comprising a tubular nut member having an annular flange portion at one end, an threaded nut portion adapted to mate with the threaded portion of the pin, and an enlarged counterbore with an inner diameter greater than the outer diameter of the sleeve.

10 23. The fastener of claim 20 wherein the interference fit of the fastener with the plurality of workpieces is about 0.0005 to about 0.0100 inches after installation.

24. The fastener of claim 20 wherein the inner surface of the sleeve is coated with low friction coating to reduce the amount of friction as the smooth cylindrical shank portion of the pin enters the sleeve.

15 25. The fastener of claim 20 wherein the fastener has a high clamp preload of about 50 to 96 percent of a minimum tensile strength required for the installed fastener.

20 26. The fastener of claim 20 wherein the fastener has a average preload of about 78% minimum tensile strength required for the installed fastener.

27. The fastener of claim 20 wherein the fastener has a grip range of about 0.136 inches and maintains about 110% of minimum mechanical performance.

28. The fastener of claim 20 wherein the fastener may be installed with
25 or without sealant.

29. The fastener of claim 20 wherein gaps between the fastener and the structure are eliminated providing good electrical conductivity.

30. The fastener of claim 20 that has a functional grip capability between the minimum and maximum thickness of the plurality of workpieces of
5 about 0.136 inches.

31. The fastener of claim 20 wherein the plurality of workpieces comprise graphite composites, titanium, aluminum, or a mixture of these components.

32. The fastener of claim 20 wherein the pin member has a protruding
10 head.

33. The fastener of claim 20 wherein the pin member has a flush head.

34. The fastener of claim 20 wherein the clearance between the collar and the threaded portion of the pin member allows sealant to escape during installation.

15

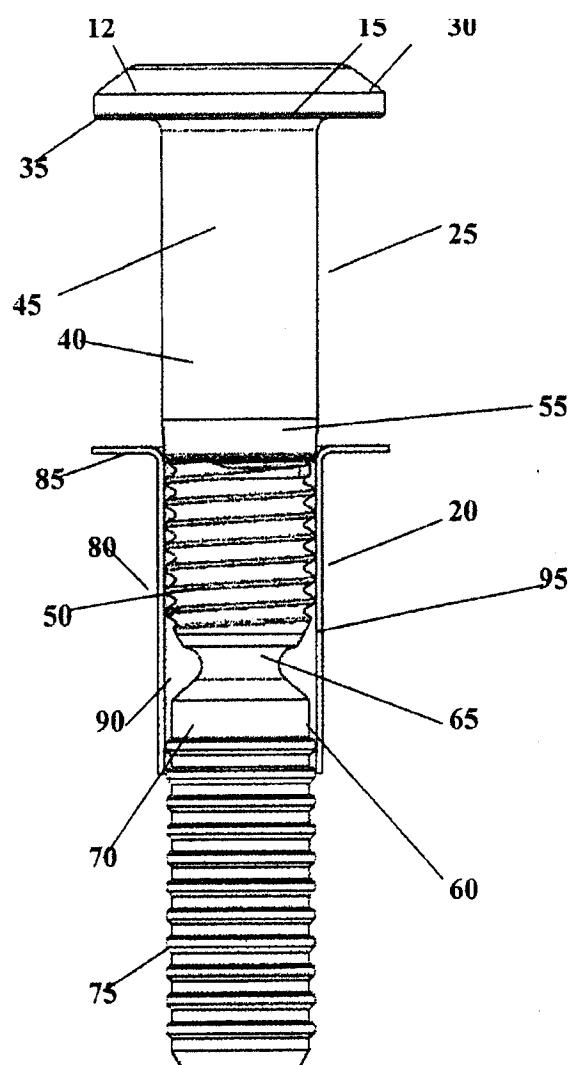
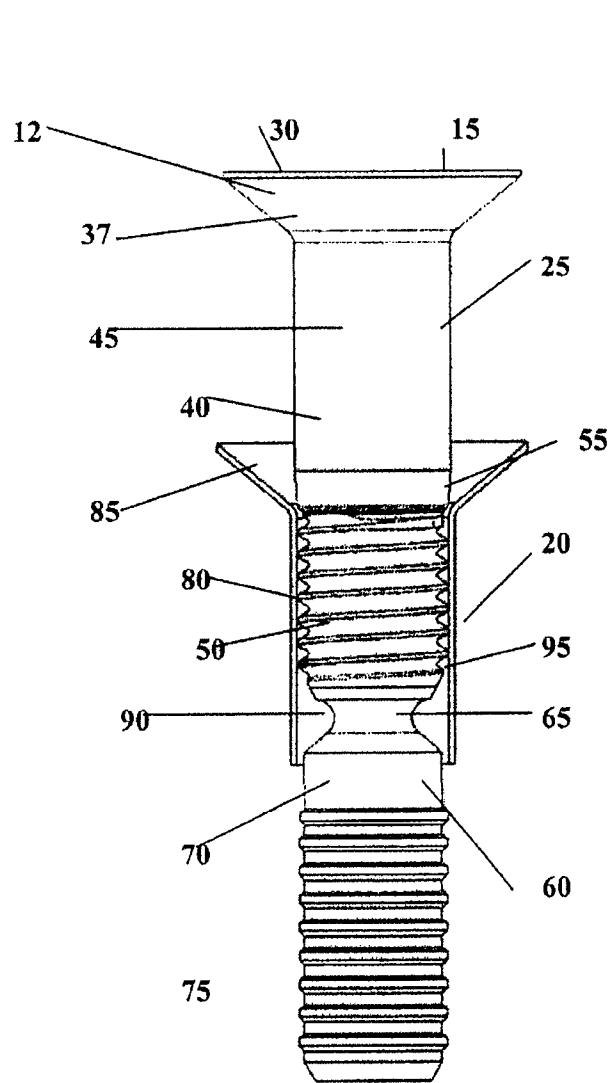
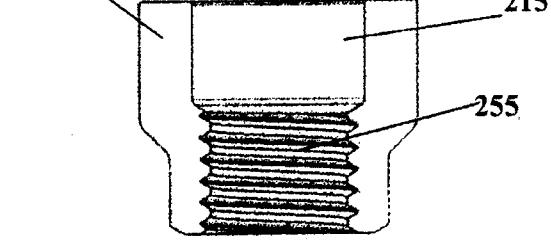
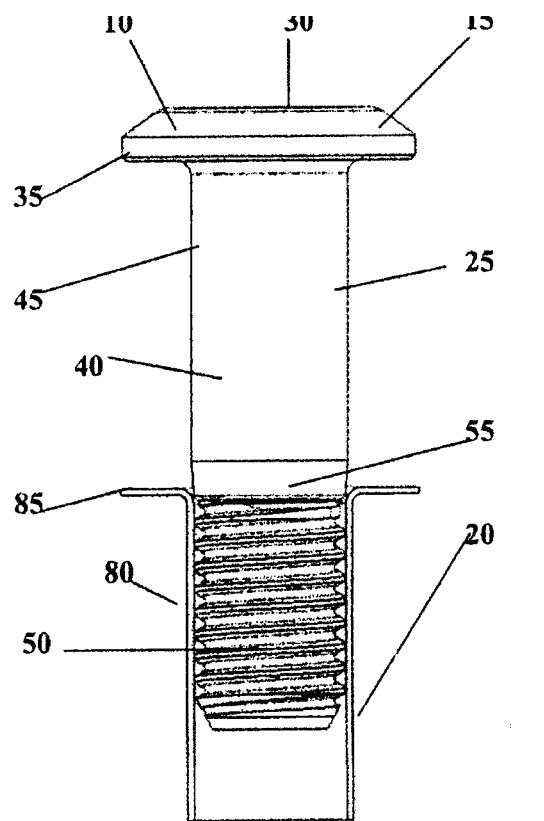
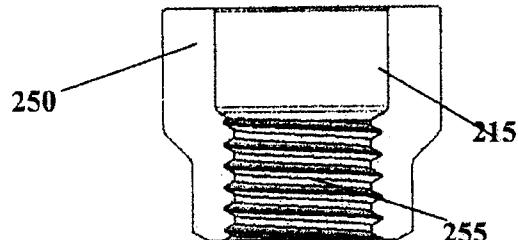
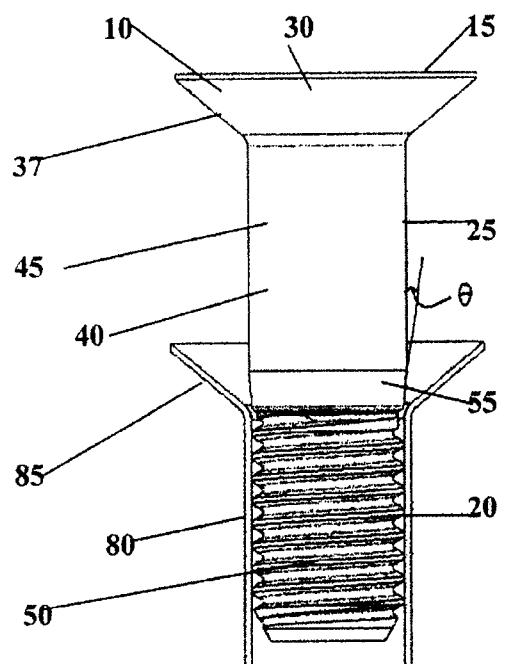
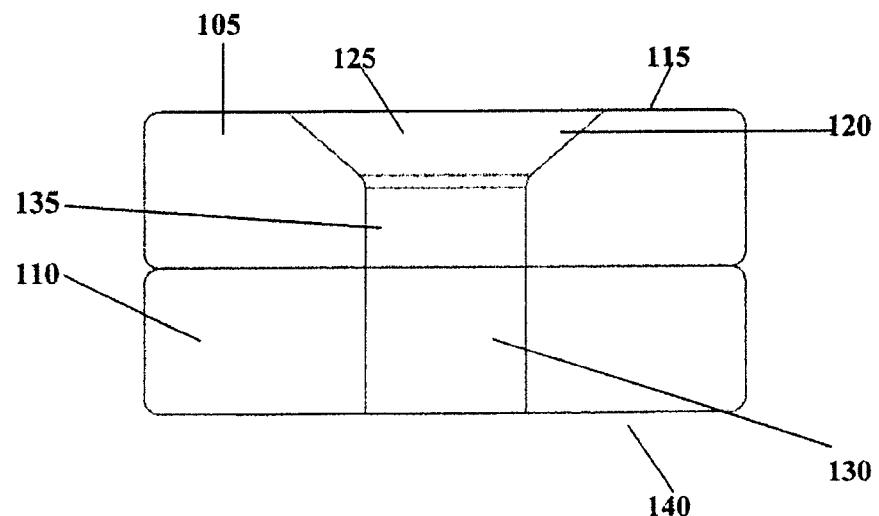
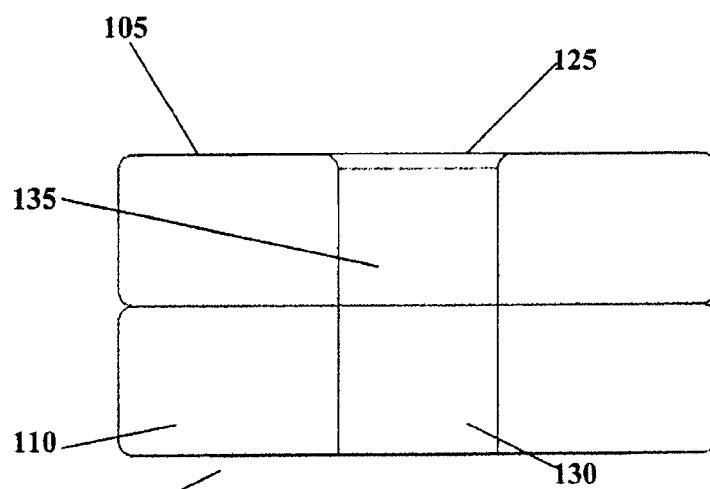
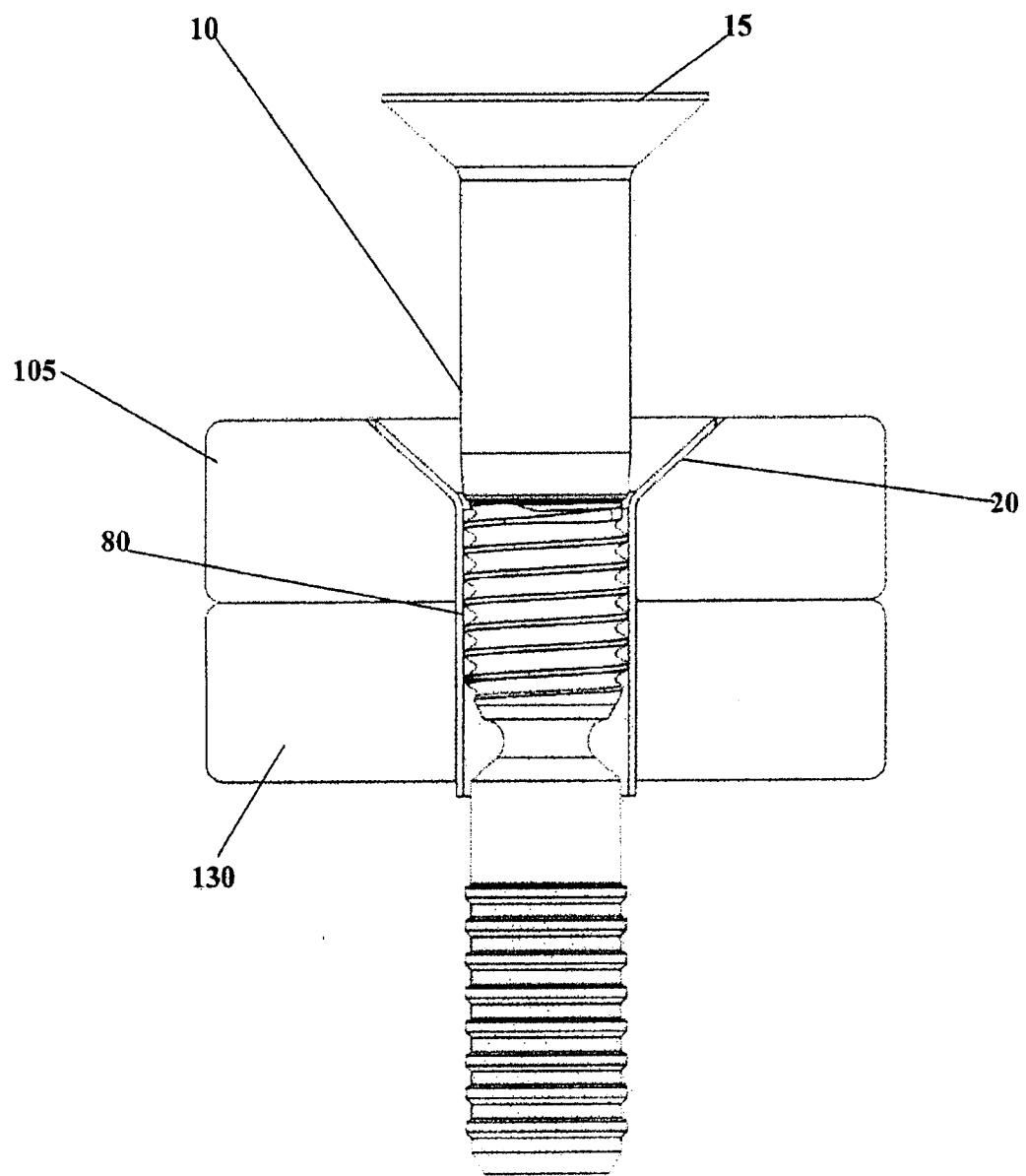


FIG. 1

FIG. 2



**FIG. 5****FIG. 6**

**FIG. 7**

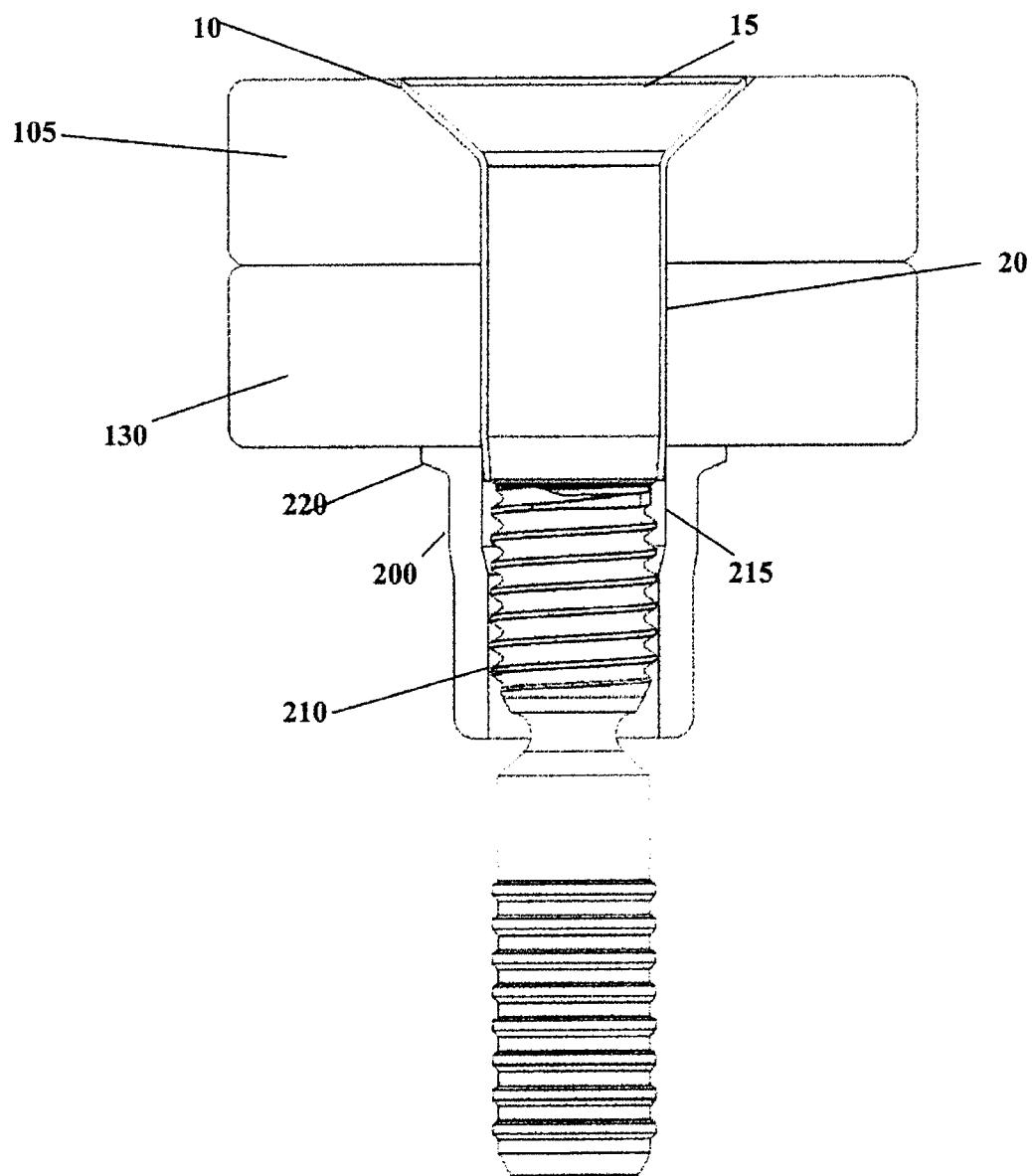
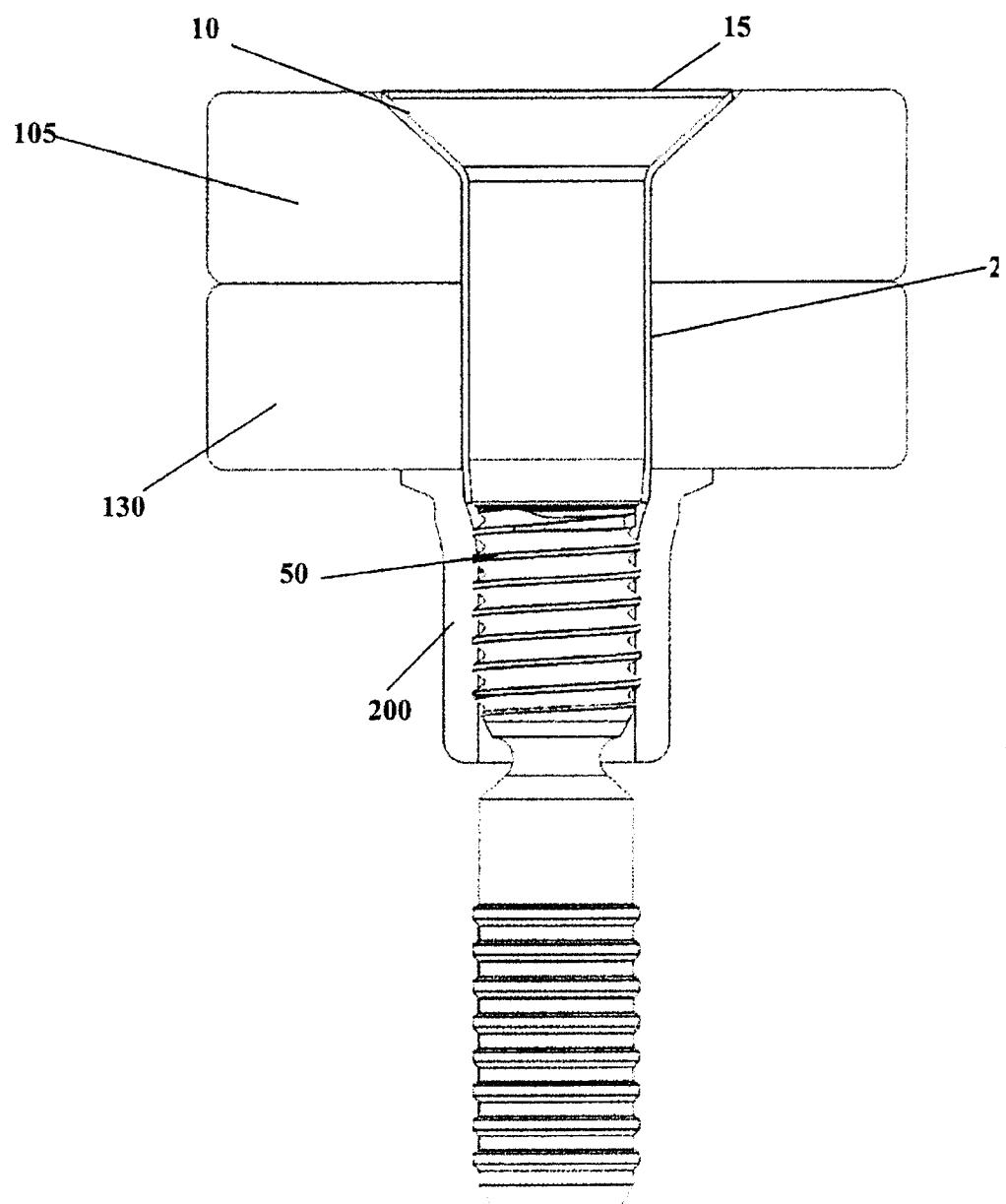


FIG. 8

**FIG. 9**

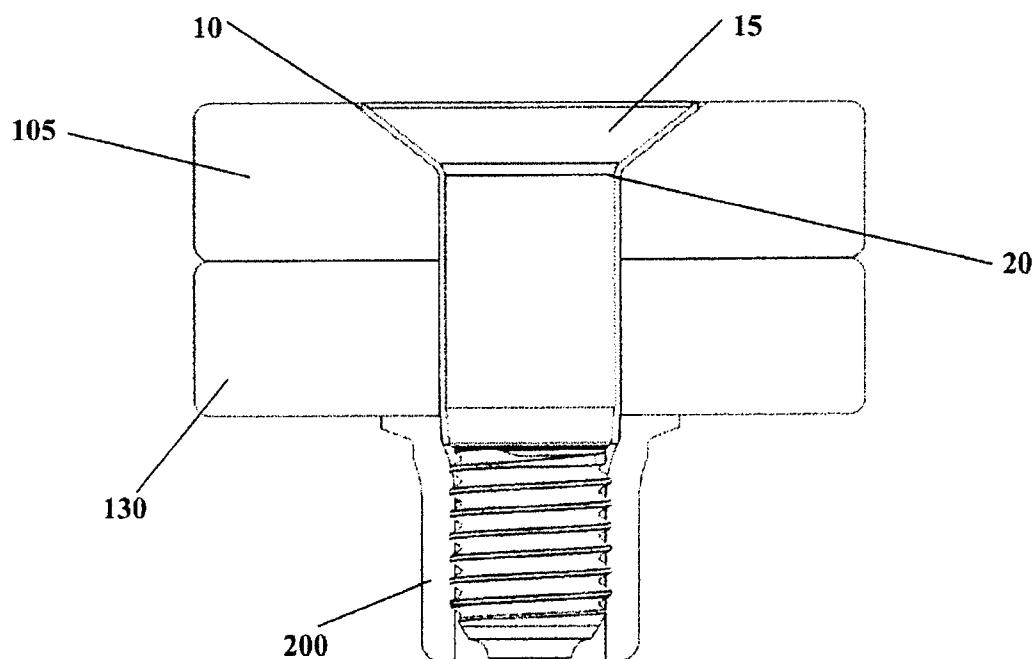


FIG. 10