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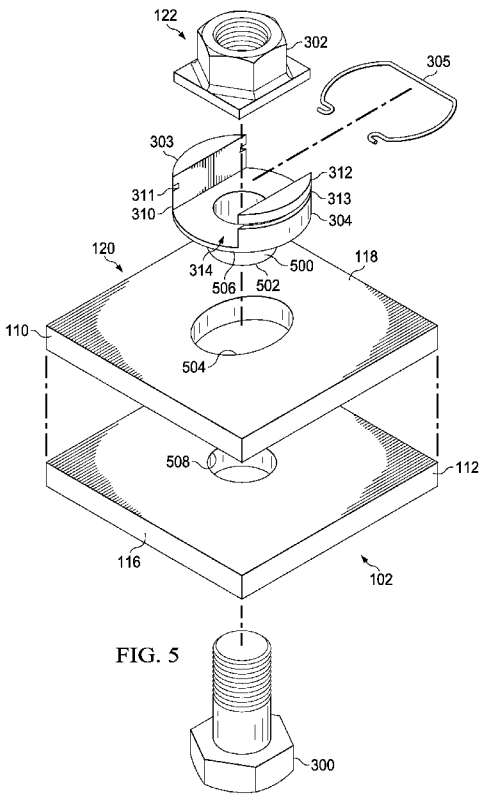


FIG. 5

(57) Abstract: A method and apparatus for fastening structures 206. A first end 220 of a body 214 is placed into a hole 504 on a first side 232 of the structures. The body has an outer surface 228 with a noncircular cross-section. A nut element 210 is positioned on a flange 216 at a second end 224 of the body. A bolt 208 is moved into a channel 222 at the first end of the body towards the nut element on the flange on the second end of the body on the first side the structures. The bolt and the nut element are fastened to each other.

WO 2014/149163 A1

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ANTI-ROTATION RIVETLESS NUT PLATE

BACKGROUND INFORMATION

Field:

The present disclosure relates generally to manufacturing and, in particular, to connecting structures to each other. Still more particularly, the present disclosure relates to a method and apparatus for connecting a stack up of structures to each other using a fastener system that includes a nut plate.

Background:

In manufacturing objects, structures are often connected to each other. For example, in manufacturing an object, such as an aircraft, many different structures are connected to each other to form assemblies for systems in the aircraft. For example, skin panels may be attached to ribs and spars. As another example, floor panels may be connected to support structures in a fuselage to form the floor of a passenger cabin.

In connecting the structures to each other, different types of connecting systems may be used. One type of connecting system is a fastener system. A fastener system may include one or more fasteners. For example, a fastener for a fastener system may be a screw. In another example, a fastener system may be a bolt and a nut.

These fasteners are used to connect structures to each other. Holes are then formed in the structure. Next, nuts and bolts are installed relative to the holes.

In some cases, access to both sides of the structure may not be feasible. For example, automated equipment may not be able to access both sides of the structure to install fasteners. As a result, a human operator or additional equipment may be used to install the fasteners. In some cases, the location of

the structure may make access to the inside fastening elements impossible.

One manner in which fasteners may be installed involves using a nut plate. A nut plate may be installed relative to a hole. The nut plate is configured to prevent movement of the nut element when the bolt is rotated. The nut plate is typically held in place through adjacent holes and rivets.

To reduce part count and installation time, rivetless nut plates may be utilized. Rivetless nut plates rely on friction to resist rotation in the hole. In composite materials, obtaining sufficient interference to resist rotation while not causing inconsistencies to the composite material may be difficult.

Therefore, it would be desirable to have a method and apparatus that takes into account at least some of the issues discussed above, as well as other possible issues.

SUMMARY

An illustrative embodiment of the present disclosure provides an apparatus comprising a body and a flange. The body has a channel extending from a first end of the body to a second end of the body. The channel has a circular cross-section configured to receive a first fastener, and the body has an outer surface that has a noncircular cross-section. The flange is associated with the second end. The flange is configured to hold a second fastener.

Another illustrative embodiment comprises a fastener system. The fastener system comprises a nut plate having a body and a flange. The body has a channel extending from a first end of the body to a second end of the body. The channel has a circular cross-section and, the body has an outer surface having a noncircular cross-section. The flange is associated with the second end of the body.

Yet another illustrative embodiment provides a method for fastening structures. A first end of a body is placed into a hole on a first side of the structures. The body has an outer surface with a noncircular cross-section. A nut element is positioned on a flange at a second end of the body. A bolt is moved into a channel at the first end of the body towards the nut element on the flange on the second end of the body on the first side of the structures. The bolt and the nut element are fastened to each other.

The features and functions can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and features thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

Figure 1 is an illustration of a manufacturing environment in accordance with an illustrative embodiment;

Figure 2 is an illustration of a fastener system in accordance with an illustrative embodiment;

Figure 3 is an illustration of a section of structures with a fastener system in accordance with an illustrative embodiment;

Figure 4 is another illustration of a section of structures with a fastener system in accordance with an illustrative embodiment;

Figure 5 is an exploded view of a section of structures with a fastener system in accordance with an illustrative embodiment;

Figure 6 is an illustration of a top view of a section of structures with a fastener system in accordance with an illustrative embodiment;

Figure 7 is an illustration of a cross-sectional view of structures and a nut plate in accordance with an illustrative embodiment;

Figure 8 is another illustration of a cross-sectional view of structures and a nut plate in accordance with an illustrative embodiment;

Figure 9 is an illustration of an outer side of a structure with a body of a nut plate in accordance with an illustrative embodiment;

Figure 10 is an illustration of a fastener system in accordance with an illustrative embodiment;

Figure 11 is an illustration of a hole in accordance with an illustrative embodiment;

Figure 12 is an illustration of a flowchart of a process for fastening structures in accordance with an illustrative embodiment;

Figure 13 is an illustration of a block diagram of an aircraft manufacturing and service method in accordance with an illustrative embodiment; and

Figure 14 is an illustration of a block diagram of an aircraft in which an illustrative embodiment may be implemented.

DETAILED DESCRIPTION

The illustrative embodiments recognize and take into account one or more different considerations. For example, the illustrative embodiments recognize and take into account that structures may be connected to each other using nut plates. The

illustrative embodiments, however, recognize and take into account that with composite structures, the use of nut plates may be more difficult than desired.

One solution may involve using nut plates that are held in place using rivets. The nut plate may have holes to receive rivets that may be placed into structures.

Use of rivets, however, may be undesirable. For example, the use of rivets requires additional holes to be formed in a composite structure. The formation of additional holes increases the chances that an inconsistency may occur. Additionally, the formation of additional holes requires more time and equipment. Further, the use of rivets may also increase the weight of the structure more than desired. Also, the nut plates that use rivets may not provide a desired spacing between fasteners.

The illustrative embodiments also recognize and take account that a gang channel may be used in place of rivets. A gang channel is a device that connects multiple nut elements together. The use of gang channels may also be impractical if a limited number of nut elements are being applied, or if the pattern of nut elements applied is irregular to the form of the gang channel. The use of gang channels also requires time to apply and adds additional costs, making them inefficient to use in some situations.

Thus, the illustrative embodiments provide a method and apparatus for fastening structures. In one illustrative example, an apparatus comprises a body and a flange. The body has a channel extending from a first end of the body to a second end of the body. The channel has a circular cross-section configured to receive a first fastener, and the body has an outer surface that has a noncircular cross-section. The flange is associated with the second end. The flange is configured to hold a second fastener. In these illustrative examples, the

first fastener may be a bolt and the second fastener may be a nut element.

With reference now to the figures and, in particular, with reference to **Figure 1**, an illustration of a manufacturing environment is depicted in accordance with an illustrative embodiment. As depicted, manufacturing environment **100** is an environment in which an assembly of structures **102** for wing **104** is performed.

In this illustrative example, operator **106** and operator **108** connect structures **102** to each other within wing **104**. As depicted, structures **102** include leading edge rib **110** and leading edge skin panel **112**.

Leading edge skin panel **112** may be connected to leading edge rib **110** through the use of fastener systems **114** installed by operator **106** and operator **108**. As depicted, operator **106** is a human operator. Operator **108** is a robotic arm.

In this illustrative example, structures **102** have first side **116** and second side **118**. Access to second side **118** may be more difficult or unavailable in this illustrative example. As a result, nut plates may be used to reduce or avoid the need for access to second side **118** when installing fasteners to connect leading edge skin panel **112** to leading edge rib **110**.

In these illustrative examples, at least one of leading edge rib **110** or leading edge skin panel **112** may be comprised of composite materials. As used herein, the phrase "at least one of", when used with a list of items, means different combinations of one or more of the listed items may be used and only one of each item in the list may be needed. For example, "at least one of item A, item B, or item C" may include, without limitation, item A, item A and item B, or item B. This example also may include item A, item B, and item C or item B and item C. In other examples, "at least one of" may be, for example, without limitation, two of item A, one of item B, and ten of item C; four of item B and seven of item C; and other suitable

combinations. The item may be a particular object, thing, or a category. In other words, at least one of means any combination of items and number of items may be used from the list, but not all of the items in the list are required.

In the illustrative examples, a composite material is formed from two more constituents with different physical or chemical properties. For example, a matrix of resin may be mixed with the reinforcement of fibers to form a composite material. The resin may be, for example, a polyester resin, a vinyl ester resin, an epoxy resin, a shape memory polymer, and other suitable types of resins. The fibers may be, for example, carbon fibers, glass fibers, polymer fibers, and other suitable types of fibers. These components may be cured to form a rigid material. The structure formed from this and other types of composite materials may be referred to as a composite structure.

As depicted, fastener systems **114** may be implemented in accordance with an illustrative embodiment such that access to second side **118** may be reduced or inaccessible. Further, fastener systems **114**, when implemented in accordance with an illustrative embodiment, may be installed more easily than with currently used fastener systems. Additionally, fastener systems **114**, when implemented in accordance with an illustrative embodiment, may reduce the occurrence of inconsistencies when at least one of leading edge rib **110** or leading edge skin panel **112** are composite structures comprised of composite materials. A more detailed illustration of section **120** with fastener system **122** in fastener systems **114** is shown in **Figure 3**.

The illustration of wing **104** in manufacturing environment **100** is not meant to limit the manner in which different illustrative embodiments may be implemented. For example, fastener systems **114** may be implemented in other types of structures **102** for other types of platforms.

For example, structures **102** may be for a monument, a landing gear assembly, an engine, a wing, a wall, furniture, and

other suitable structures. In these illustrative examples, structures **102** may be a platform selected from one of a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, and other suitable types of platforms.

With reference now to **Figure 2**, an illustration of a fastener system is depicted in accordance with an illustrative embodiment. Fastener system **200** is an example of a fastener that may be used in fastener systems **114** to connect structures to each other, such as leading edge skin panel **112** to leading edge rib **110** in **Figure 1**.

In this illustrative example, fastener system **200** comprises first fastener **202** and second fastener **204**. First fastener **202** and second fastener **204** may be used to connect structures **206** to each other. In these illustrative examples, first fastener **202** may be bolt **208** and second fastener **204** may be nut element **210**. Bolt **208** and nut element **210** are configured to engage each other. This engagement may occur when a torque is applied to at least one of bolt **208** and nut element **210**.

As depicted, structures **206** are two or more structures. The structures may include at least one composite structure in the illustrative examples. As depicted, hole **212** extends through structures **206**.

As depicted, fastener system **200** also may include body **214** and flange **216**. These two components may take the form of nut plate **218** in these illustrative examples.

Body **214** has first end **220** and second end **222**. Body **214** has channel **224** extending from first end **220** to second end **222** of body **214**. Additionally, channel **224** has circular cross-section **226**. Circular cross-section **226** is substantially circular in these illustrative examples. In particular,

circular cross-section **226** is configured to receive first fastener **202**. Thus, some deviations may be present from a perfect circle for circular cross-section **226**. These deviations may be specified by tolerance based on first fastener **202**. In other words, the tolerance may specify that a deviation from a perfect circle may be such that channel **224** is able to receive first fastener **202** in the form of bolt **208** such that bolt **208** may engage second fastener **204** in the form of nut element **210** in this illustrative example.

As depicted, body **214** has outer surface **228** with noncircular cross-section **230**. In other words, the cross-section of outer surface **228** has a different shape from the cross-section of channel **224** extending through body **214** in these illustrative examples. Noncircular cross-section **230** is a substantially noncircular cross-section in these illustrative examples. In the illustrative example, noncircular cross-section **230** may take various forms. For example, noncircular cross-section **230** may be a cross-section having a shape selected from one of an ellipse, an egg shape, an oval, a tri-oval, a trefoil, a curvilinear triangle, a teardrop, a quatrefoil, a rounded corner parallelogram, a pentagon, a hexagon, a heptagon, an octagon, a nonagon, a decagon, or some other suitable shape.

Flange **216** is configured to hold second fastener **204**, such as nut element **210**. As depicted, flange **216** is associated with body **214** at second end **222** of body **214**. When one component is "associated" with another component, the association is a physical association in the depicted examples. For example, a first component, flange **216**, may be considered to be associated with a second component, body **214**, by being secured to the second component, bonded to the second component, mounted to the second component, welded to the second component, fastened to the second component, and/or connected to the second component in some other suitable manner. The first component also may be connected to the second component using a third component. The

first component may also be considered to be associated with the second component by being formed as part of and/or an extension of the second component.

In the different illustrative examples, flange **216** may be, for example, formed as part of second end **222** of body **214**. In other illustrative examples, flange **216** may be a separate structure from body **214** and may be configured to be connected to second end **222** of body **214**. Further, flange **216** may be removably connected to second end **222** of body **214** in some illustrative examples.

In these illustrative examples, structures **206** are arranged in a stack up. Hole **212** extends from first side **232** of structures **206** to second side **234** of structures **206**.

First end **220** of body **214** may be placed into hole **212** on first side **232** of structures **206**. The placement of body **214** with flange **216** associated with body **214** results in flange **216** being located on first side **232** of structures **206**. In this illustrative example, hole **212** also has noncircular cross-section **238**. Noncircular cross-section **238** is substantially the same shape as noncircular cross-section **230**. Noncircular cross-section **230** may be slightly smaller. Noncircular cross-section **230** of outer surface **228** is selected such that an interference fit may still result between body **214** and hole **212** through additional processes, such as cold working.

Noncircular cross-section **230** of body **214** corresponding to noncircular cross-section **238** of hole **212** may reduce movement, such as rotation, of nut plate **218** within hole **212**. This reduction in movement may occur when a force, such as a torque, is applied to at least one of bolt **208** or nut element **210**.

With this type of cross-section, the interference fit may not need to be as tight as in other situations. As a result, the generation of inconsistencies in hole **212**, structures **206**, or both from installing nut plate **218** in hole **212** may be reduced. Further, the particular shape of noncircular cross-

section **230** may be selected such that the creation of inconsistencies in hole **212**, structures **206**, or both from tightening at least one of bolt **208** or nut element **210** to connect structures **206** to each other may be reduced.

As depicted, body **214** may be comprised of a first material selected from at least one of a metal, a plastic, steel, aluminum, titanium, copper, polycarbonate, a composite material, or some other suitable material. Flange **216** is comprised of a second material selected from one of a metal, a plastic, steel, aluminum, titanium, copper, polycarbonate, a composite material, or some other suitable material. Body **214** and flange **216** may be comprised of the same material or different material in these illustrative examples.

Nut element **210** may be placed on flange **216**. In these illustrative examples, flange **216** may have securing configuration **240**. Securing configuration **240** is a shape of flange **216** that allows flange **216** to hold nut element **210** for various orientations of structures **206**. For example, first side **232** may be substantially vertical, substantially horizontal to the floor, or some other orientation. With these different orientations, flange **216** may hold nut element **210** in place for engagement with bolt **208**.

As depicted, bolt **208** may be moved into hole **212** from second side **234** to structures **206**. This movement of bolt **208** results in bolt **208** moving into channel **224** from first end **220** of body **214**. The movement of bolt **208** may be such that bolt **208** may be engaged with nut element **210** held by flange **216**. This positioning may be such that nut element **210** and bolt **208** may be engaged with each other through the use of force to rotate bolt **208** in a manner that secures bolt **208** to nut element **210**. As a result, structures **206** are connected to each other.

The illustration of fastener system **200** in **Figure 2** is not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented.

Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

For example, in other illustrative examples, flange **216** may be configured to hold bolt **208** in place. In this example, nut element **210** may be turned to engage bolt **208** in a manner that secures structures **206** to each other.

With reference now to **Figure 3**, an illustration of a section of structures with a fastener system is depicted in accordance with an illustrative embodiment. In this illustrative example, a more detailed illustration of section **120** of structures **102** with fastener system **122** is depicted in accordance with an illustrative embodiment. In this illustrative example, an isometric view of section **120** is shown.

As seen in this illustrative example, fastener system **122** includes a number of components. As depicted, fastener system **122** includes bolt **300**, nut element **302**, nut plate **303**, and retention device **305**.

Bolt **300** is an example of a physical implementation for bolt **208** shown in block form in **Figure 2**. Nut element **302** is an example of a physical implementation for nut element **210** shown in block form in **Figure 2**.

Flange **304** is a component of nut plate **303** in this example. As depicted, flange **304** is an example of one physical implementation for flange **216** shown in block form in **Figure 2**. Flange **304** has a configuration that is configured to maintain a position of nut element **302** when force is applied to bolt **300** in the direction of arrow **306**. Additionally, retention device **305** may resist movement in the direction of arrow **307**. Additionally, a body is another component of nut plate **303** but not seen in this view.

In this illustrative example, flange **304** has wall **310** and wall **312** that defines channel **314**.

Nut element **302** may be placed into and held within channel **314**. Retention device **305** is configured to hold nut element **302** within channel **314**. In this illustrative example, retention device **305** takes the form of a retention clip and may be placed into groove **311** and groove **313** in flange **304**.

As depicted, wall **310** and wall **312** of flange **304** is configured to reduce or prevent rotation of nut element **302** when bolt **300** is rotated to engage nut element **302** and connect structures **102** to each other.

With reference next to **Figure 4**, another illustration of a section of structures with a fastener system is depicted in accordance with an illustrative embodiment. In this view, another isometric view of section **120** is shown. Bolt **300** can be seen in this view. Bolt **300** extends from first side **116** to second side **118** to engage nut element **302**.

With reference now to **Figure 5**, an exploded view of a section of structures with a fastener system is depicted in accordance with an illustrative embodiment. In this exploded view of section **120**, body **500** is seen.

In this illustrative example, body **500** has first end **502** that may extend into noncircular hole **504** on second side **118** of structures **102** when body **500** is placed into noncircular hole **504**. In particular, first end **502** may extend into the portion of noncircular hole **504** in leading edge rib **110**. In this illustrative example, first end **502** has a noncircular shape. As depicted, flange **304** is connected to second end **506** of body **500**. Hole **508** in leading edge skin panel **112** is circular. Hole **508** does not need to be noncircular because body **500** is not inserted into hole **508** in this example. Instead, hole **508** may receive bolt **300**.

With reference next to **Figure 6**, an illustration of a top view of a section of structures with a fastener system is

depicted in accordance with an illustrative embodiment. In this example, the top view is a view of second side **118** of structures **102**. In this depicted view, nut plate **303** is shown without bolt **300** and nut element **302**.

Turning now to **Figure 7**, an illustration of a cross-sectional view of structures and a nut plate is depicted in accordance with an illustrative embodiment. The cross-sectional view of structures **102** with nut plate **303** is shown taken along lines **7-7** in **Figure 6**.

Next in **Figure 8**, another illustration of a cross-sectional view of structures and a nut plate is depicted in accordance with an illustrative embodiment.

The cross-sectional view of structures **102** with nut plate **303** are shown taken along lines **8-8** in **Figure 6**. A view of inner side **800** is shown and described with reference to **Figure 9** below.

In **Figure 9**, an illustration of an outer side of a structure with a body of a nut plate is depicted in accordance with an illustrative embodiment. In this view of outer side **800** of leading edge rib **110**, first end **502** of body **500** also is seen within noncircular hole **504**. In this illustrative example, channel **314** has a circular cross-section. As depicted, channel **314** is configured to receive bolt **300**.

As depicted, body **500** has exterior wall **900**. Exterior wall **900** has a noncircular cross-section in this illustrative example. For example, dimension **902** may be about 0.300 inches, while dimension **904** may be about 0.305 inches in this illustrative example. The noncircular cross-section of exterior wall **900** corresponds to the shape of noncircular hole **504**. In other words, noncircular hole **504** also has a noncircular cross-section.

With reference next to **Figure 10**, an illustration of a fastener system is depicted in accordance with an illustrative embodiment. In this depicted example, fastener system **1000**

includes bolt **1002**, nut element **1004**, nut plate **1006**, and retention device **1007**.

In this illustrative example, nut plate **1006** includes body **1008** and flange **1010**. As depicted, body **1008** and flange **1010** are separate pieces. These two pieces may be connected to each other prior to bolt **1002** and nut element **1004** engaging each other.

Turning now to **Figure 11**, an illustration of a hole is depicted in accordance with an illustrative embodiment. In this illustrative embodiment, hole **1100** may be an example of one implementation for noncircular hole **504** in **Figure 5**. As depicted, hole **1100** has a noncircular shape. The noncircular shape of hole **1100** corresponds to the noncircular shape of a nut plate in accordance with an illustrative embodiment. For example, the noncircular shape is an elliptical cross-section in this illustrative example.

As depicted, hole **1100** has center **1102**. Similarly, cutter **1104** has center **1106**. Center **1106** of cutter **1104** is offset from center **1102** of hole **1100** in this illustrative example. Path **1108** may be formed using the offset of center **1106** of cutter **1104** to center **1102** of hole **1100**. In these illustrative examples, the offset varies such that path **1108** has an elliptical shape. In other examples, path **1108** may have another shape. In order to form hole **1100**, center **1106** of cutter **1104** moves along path **1108**. In this manner, cutter **1104** may create hole **1100**. As depicted, hole **1100** may be created to correspond to and receive an outer surface with a noncircular cross-section in a body of a nut plate, such as nut plate **303**.

The illustration of the fastener systems i**n Figures 3-11** are only provided as examples of some implementations that may be used in accordance with an illustrative embodiment. Other illustrative examples may have other shapes for the different components illustrated.

The different components shown in **Figures 1** and **3-11** may be combined with components in **Figure 2**, used with components in **Figure 2**, or a combination of the two. Additionally, some of the components in **Figures 1** and **3-11** may be illustrative examples of how components shown in block form in **Figure 2** can be implemented as physical structures. For example, other methods may be used for creating hole **1100**. For example, laser drilling, electric discharge machining, and other processes may be implemented.

Turning next to **Figure 12**, an illustration of a flowchart of a process for fastening structures is depicted in accordance with an illustrative embodiment. The process illustrated **Figure 12** may be implemented in a manufacturing environment, such as manufacturing environment **100** in **Figure 1**, to connect structures to each other. In particular, the structures may be connected to each other using fastener system **200** in **Figure 2**.

The process begins by forming the hole in the stack up of the structures prior to placing the first end of the body into the hole on the first side of the structures (operation **1200**). In operation **1200**, some holes in the stack up of structures may be circular while other holes may be noncircular. The circular holes are for structures through which the body of a nut plate is received in this illustrative example. The body has an outer surface with a noncircular cross-section. In the illustrative example, only one structure may be noncircular while the other structures in the stack up are circular. The circular holes in the structures are configured to receive a bolt in this illustrative example. The noncircular hole may be formed separately from the circular holes.

A nut element is positioned on a flange at a second end of the body (operation **1202**). A process similar to cold working is used to install the nutplate into the rib with a slight interference level. The process then moves a bolt into a channel at the first end of the body towards the nut element on

the flange on the second end of the body on the first side of the structures (operation **1204**).

The bolt and the nut element are fastened to each other (operation **1206**), with the process terminating thereafter. The bolt and the nut element are fastened to each other by applying a force, such as a torque, to the bolt while the nut element is held by the flange. As a result the structures are fastened to each other.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams may represent a module, a segment, a function, and/or a portion of an operation or step.

The illustrative embodiments of the disclosure may be described in the context of aircraft manufacturing and service method **1300** as shown in **Figure 13** and aircraft **1400** as shown in **Figure 14**. Turning first to **Figure 13**, an illustration of a block diagram of an aircraft manufacturing and service method is depicted in accordance with an illustrative embodiment. During pre-production, aircraft manufacturing and service method **1300** may include specification and design **1302** of aircraft **1400** in **Figure 14** and material procurement **1304**.

During production, component and subassembly manufacturing **1306** and system integration **1308** of aircraft **1400** in **Figure 14** takes place. Thereafter, aircraft **1400** in **Figure 14** may go through certification and delivery **1310** in order to be placed in service **1312**. While in service **1312** by a customer, aircraft **1400** in **Figure 14** is scheduled for routine maintenance and service **1314**, which may include modification, reconfiguration, refurbishment, and other maintenance or service.

Each of the processes of aircraft manufacturing and service method **1300** may be performed or carried out by a system

integrator, a third party, and/or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, a leasing company, a military entity, a service organization, and so on.

With reference now to **Figure 14**, an illustration of a block diagram of an aircraft is depicted in which an illustrative embodiment may be implemented. In this example, aircraft **1400** is produced by aircraft manufacturing and service method **1300** in **Figure 13** and may include airframe **1402** with systems **1404** and interior **1406**. Examples of systems **1404** include one or more of propulsion system **1408**, electrical system **1410**, hydraulic system **1412**, and environmental system **1414**. Any number of other systems may be included. Although an aerospace example is shown, different illustrative embodiments may be applied to other industries, such as the automotive industry.

Apparatuses and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method **1300** in **Figure 13**. The different illustrative examples may be implemented in component and subassembly manufacturing **1306** to connect structures to each other to form assemblies. Further, the illustrative examples also may be used during system integration **1308** with assembling aircraft **1400**. Illustrative embodiments also may be used during maintenance and service **1314**. The illustrative embodiments may be used to connect structures to each other during maintenance, refurbishment, upgrades, and other operations. The use of a number of the different illustrative embodiments may substantially expedite the assembly of and/or reduce the cost of aircraft **1400**.

The illustrative embodiments provide a method for connecting structures to each other using fastener systems. In the illustrative examples, the nut plate has a body that has an exterior surface that has a noncircular cross-section. Although an ellipse, the depicted shape of the noncircular cross-section, has been shown in the illustrative examples, other shapes may be used other than an elliptical cross-section such that the shapes allow for increased resistance to rotation of the body of the nut plate within the hole when a torque is applied to tighten a bolt to a nut element installed in the hole and nut plate. In this manner, cold working may be used to create a slight interference fit to secure the nut plate to the composite structure. With the use of the nut plate, the number of holes formed in composite structures may be reduced when rivets are unnecessary. Further, weight caused by the use of other types of techniques, such as those using gang channels, may be avoided. Of course, the different illustrative embodiments may be applied to other types of structures other than composite structures. For example, the illustrative embodiments may be applied to metal, plastic, and other structures that employ other types of materials.

The different illustrative embodiments may be applied in a number of different ways. For example, the fastener system may be employed by at least one of a human operator, automated equipment, equipment controlled by human operators, or other suitable types of operators.

Further, the disclosure comprises embodiments according to the following clauses:

1. An apparatus comprising:

a body having a channel extending from a first end of the body to a second end of the body, wherein the channel has a circular cross-section configured to receive a first fastener, and wherein the body has an outer surface that has a noncircular cross-section; and

a flange associated with the second end, wherein the flange is configured to hold a second fastener.

2. The apparatus of clause 1, wherein the flange is a separate structure from the body and is configured to be connected to the second end of the body.

3. The apparatus of clause 1, wherein the flange is part of the second end of the body.

4. The apparatus of clause 1, wherein the flange is configured to hold the second fastener in a position in which a hole in the second fastener is aligned with the channel and is positioned to receive the first fastener.

5. The apparatus of clause 1, wherein the first fastener is a bolt and the second fastener is a nut element.

6. The apparatus of clause 1 further comprising:

structures having a hole extending through the structures, wherein the first end of the body is configured to be placed into the hole on a first side of the structures.

7. The apparatus of clause 1, wherein the body and the flange form a nut plate.

8. The apparatus of clause 1, wherein the body is comprised of a first material selected from at least one of a metal, a plastic, steel, aluminum, titanium, copper, polycarbonate, or a composite material, and wherein the flange is comprised of a second material selected from one of a metal, a plastic, steel, aluminum, titanium, copper, polycarbonate, or a composite material.

9. The apparatus of clause 1, wherein the body is configured to be placed into a hole in a stack up of structures, wherein the hole has the noncircular cross-section.

10. The apparatus of clause 1, wherein the noncircular cross-section has a shape selected from one of an ellipse, an egg shape, an oval , a tri-oval, a trefoil, a curvilinear triangle, a teardrop, a quatrefoil, a rounded corner parallelogram, a pentagon, a hexagon, a heptagon, an octagon, a nonagon, and a decagon.

11. The apparatus of clause 9, wherein the structures are for a platform selected from one of a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, and a building.

12. A fastener system comprising:

a nut plate having a body and a flange, wherein the body has a channel extending from a first end of the body to a second end of the body, wherein the channel has a circular cross-section, wherein the body has an outer surface having a noncircular cross-section, and wherein the flange is associated with the second end of the body.

13. The fastener system of clause 12 further comprising:

a bolt; and

a nut element configured to engage the bolt, wherein the circular cross-section is configured to receive the bolt and the flange is configured to hold the nut element.

14. The fastener system of clause 12, wherein the flange is a separate structure from the body and is configured to be connected to the second end of the body.

15. The fastener system of clause 12, wherein the flange is formed as part of the second end of the body.

16. A method of fastening structures, the method comprising:

placing a first end of a body into a hole on a first side of the structures, wherein the body has an outer surface with a noncircular cross-section;

positioning a nut element on a flange at a second end of the body;

moving a bolt into a channel at the first end of the body towards the nut element on the flange on the second end of the body on the first side of the structures; and

fastening the bolt and the nut element to each other, wherein the structures are fastened to each other.

17. The method of clause 16 further comprising:

forming the hole in a stack up of the structures prior to placing the first end of the body into the hole on the first side of the structures.

18. The method of clause 16, wherein fastening the bolt and the nut element to each other comprises:

applying a torque to the bolt while the nut element is held by the flange.

19. The method of clause 16 further comprising:

connecting the flange to the second end of the body.

20. The method of clause 16, wherein positioning the first end of the body in the hole on the first side of the structures comprises:

positioning the first end of the body in the hole on the first side of the structures, wherein the structures include at least one composite structure.

21. The method of clause 16, wherein fastening the bolt and the nut element to each other, wherein the structures are fastened to each other comprises:

fastening the bolt and the nut element to each other, wherein the structures are fastened to each other and wherein the structures are for a platform selected from one of a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, and a building.

The description of the different illustrative embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other illustrative embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

CLAIMS:

What is claimed is:

1. An apparatus comprising:
a body (214) having a channel (224) extending from a first end (220) of the body (214) to a second end (224) of the body (214), wherein the channel (224) has a circular cross-section (226) configured to receive a first fastener (202), and wherein the body (214) has an outer surface (228) that has a noncircular cross-section (230); and
a flange (216) associated with the second end (224), wherein the flange (216) is configured to hold a second fastener (204).

2. The apparatus of claim 1, wherein the flange (216) is a separate structure from the body (214) and is configured to be connected to the second end (224) of the body (214).

3. The apparatus of any preceding claim, wherein the flange (216) is part of the second end (224) of the body (214).

4. The apparatus of any preceding claim, wherein the flange (216) is configured to hold the second fastener (204) in a position in which a hole (212) in the second fastener (204) is aligned with the channel (224) and is positioned to receive the first fastener (202).

5. The apparatus of any preceding claim, wherein the first fastener (202) is a bolt (208) and the second fastener (204) is a nut element (210).

6. The apparatus of any preceding claim further comprising:
structures (206) having a hole (212) extending through the structures (206), wherein the first end (220) of the body (214)

is configured to be placed into the hole (212) on a first side (232) of the structures (206).

7. The apparatus of any preceding claim, wherein the body (214) and the flange (216) form a nut plate (218).

8. The apparatus of any preceding claim, wherein the body (214) is comprised of a first material selected from at least one of a metal, a plastic, steel, aluminum, titanium, copper, polycarbonate, or a composite material, and wherein the flange (216) is comprised of a second material selected from one of a metal, a plastic, steel, aluminum, titanium, copper, polycarbonate, or a composite material.

9. The apparatus of any preceding claim, wherein the body (214) is configured to be placed into a hole (212) in a stack up of structures (206), wherein the hole (212) has the noncircular cross-section (230).

10. A method of fastening structures (206), the method comprising:

placing a first end (220) of a body (214) into a hole (212) on a first side (232) of the structures (206), wherein the body (214) has an outer surface (228) with a noncircular cross-section (230);

positioning (1202) a nut element (210) on a flange (216) at a second end (224) of the body (214);

moving (1204) a bolt (208) into a channel (224) at the first end (220) of the body (214) towards the nut element (210) on the flange (216) on the second end (224) of the body (214) on the first side (232) of the structures (206); and

fastening (1206) the bolt (208) and the nut element (210) to each other, wherein the structures (206) are fastened to each other.

11. The method of claim 10 further comprising:

forming (1200) the hole (212) in a stack up of the structures (206) prior to placing the first end (220) of the body (214) into the hole (212) on the first side (232) of the structures (206).

12. The method of any of claims 10-11, wherein fastening the bolt (208) and the nut element (210) to each other comprises:

applying a torque to the bolt (208) while the nut element (210) is held by the flange (216).

13. The method of any of claims 10-12 further comprising:

connecting the flange (216) to the second end (224) of the body (214).

14. The method of any of claims 10-13, wherein positioning the first end (220) of the body (214) in the hole (212) on the first side (232) of the structures (206) comprises:

positioning the first end (220) of the body (214) in the hole (212) on the first side (232) of the structures (206), wherein the structures (206) include at least one composite structure.

15. The method of any of claims 10-14, wherein fastening the bolt (208) and the nut element (210) to each other, wherein the structures (206) are fastened to each other comprises:

fastening the bolt (208) and the nut element (210) to each other, wherein the structures (206) are fastened to each other and wherein the structures (206) are for a platform selected from one of a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an

automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, and a building.

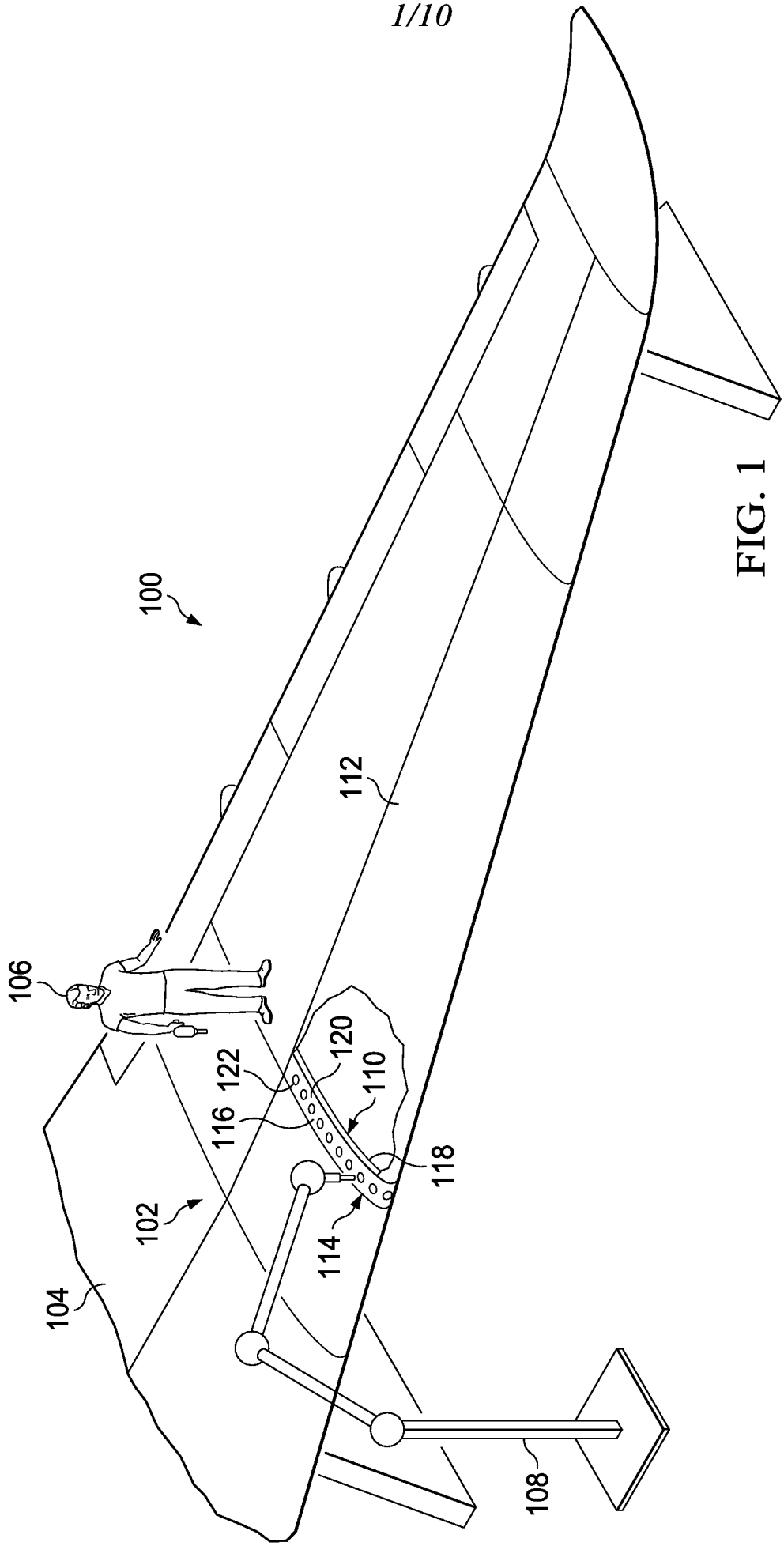


FIG. 1

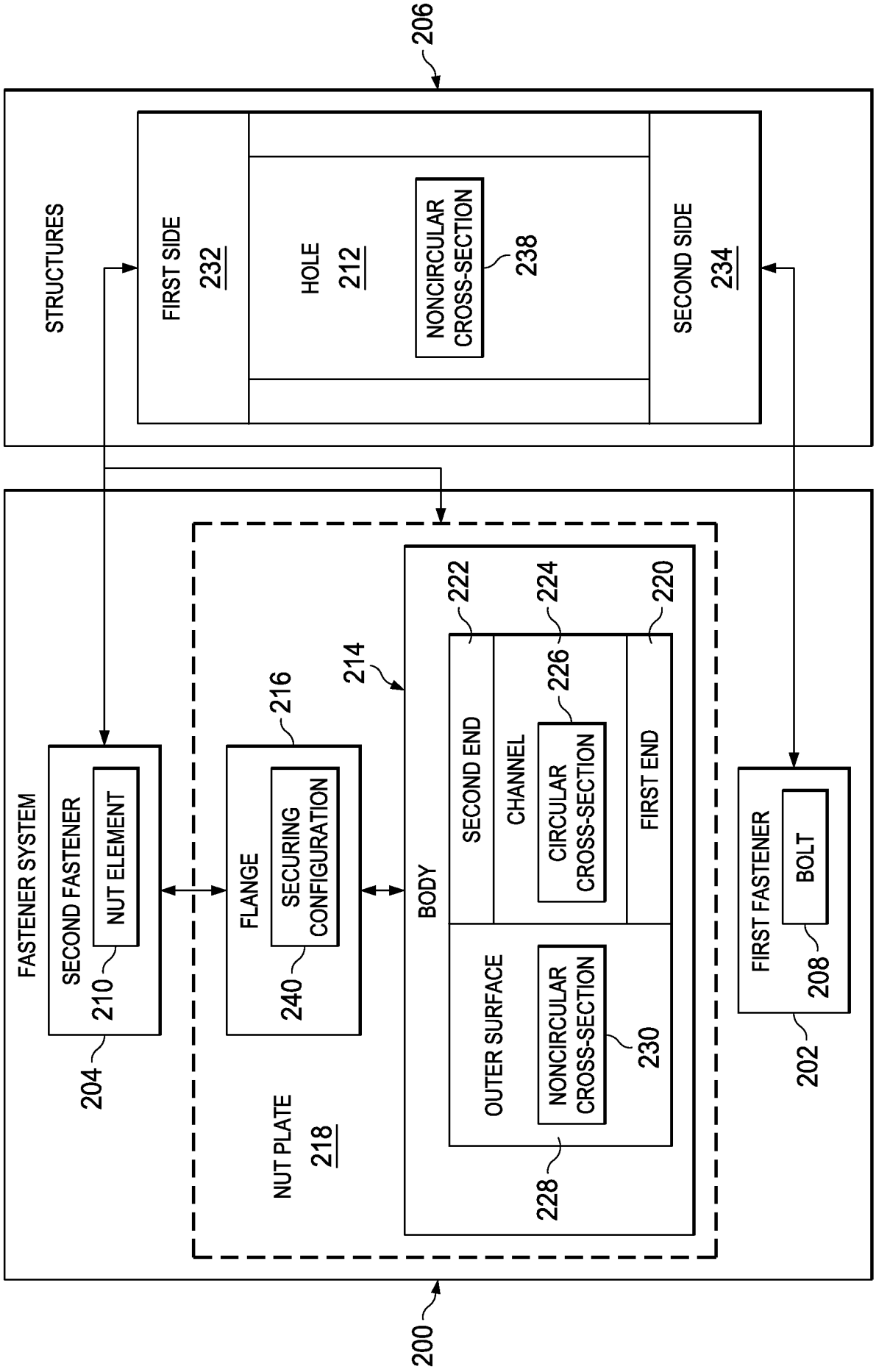

206
STRUCTURES
FIRST SIDE
232
HOLE
212
NONCIRCULAR CROSS-SECTION
238
SECOND SIDE
234
FASTENER SYSTEM
SECOND FASTENER
NUT ELEMENT
210
204
FLANGE
SECURING CONFIGURATION
240
216
214
NUT PLATE
218
BODY
SECOND END
222
CHANNEL
224
CIRCULAR CROSS-SECTION
226
FIRST END
220
OUTER SURFACE
NONCIRCULAR CROSS-SECTION
230
228
FIRST FASTENER
BOLT
208
202
200

FIG. 2

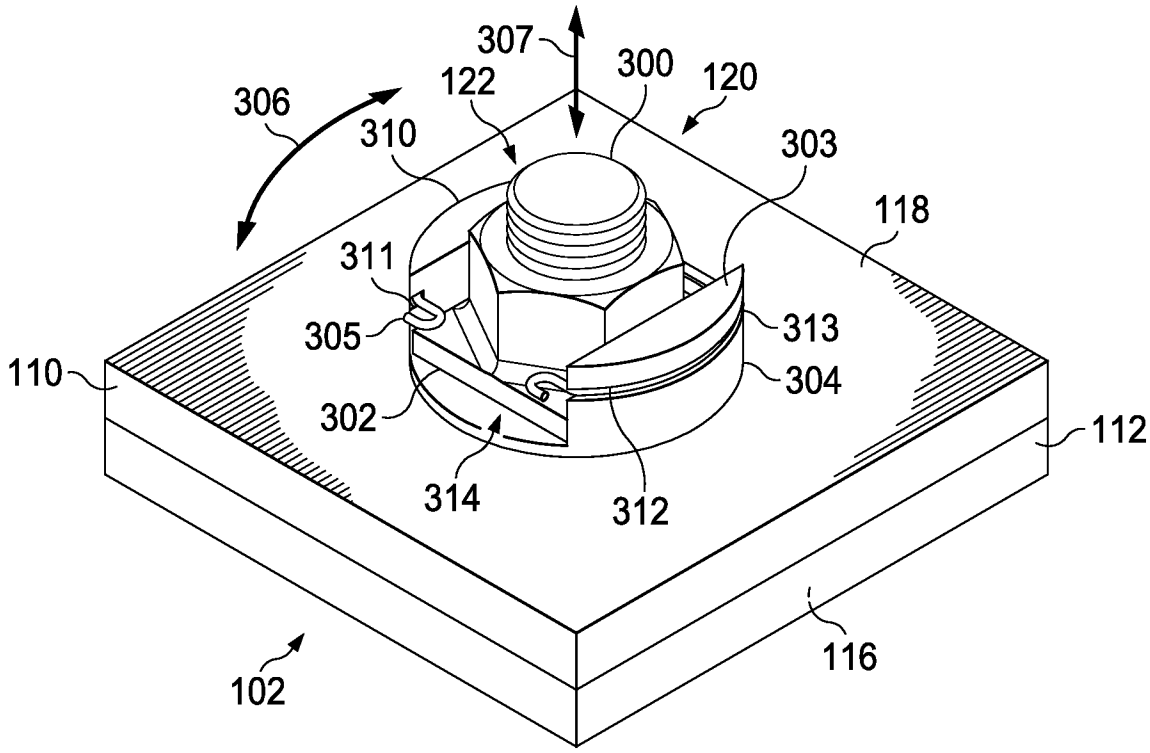

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FIG. 3

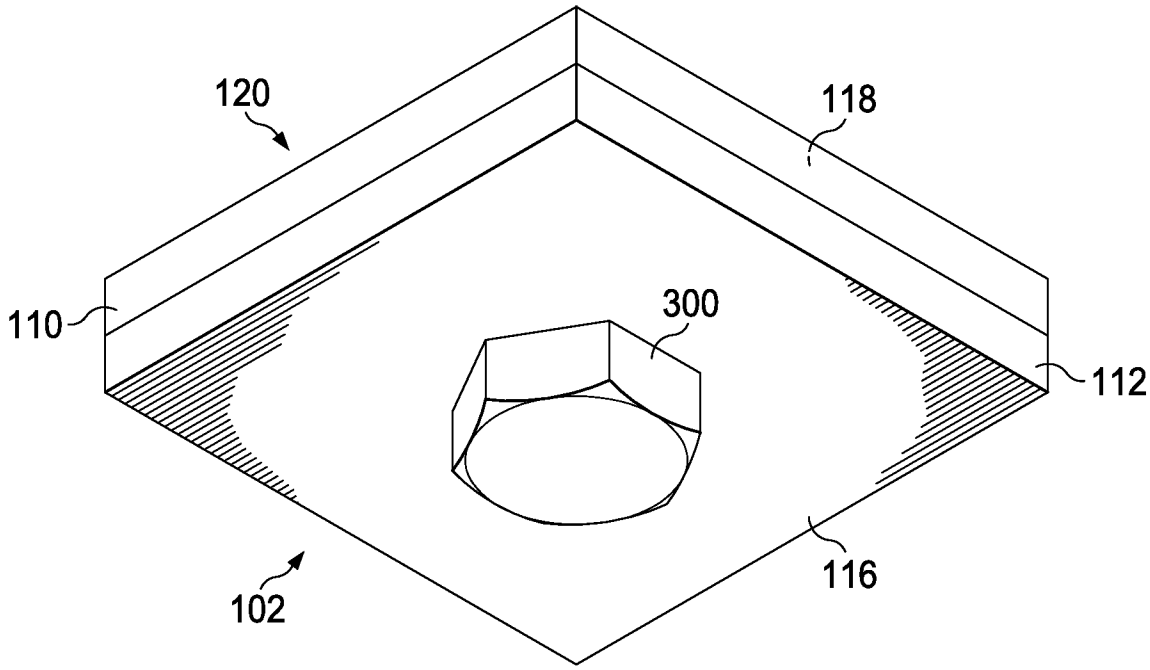

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FIG. 4

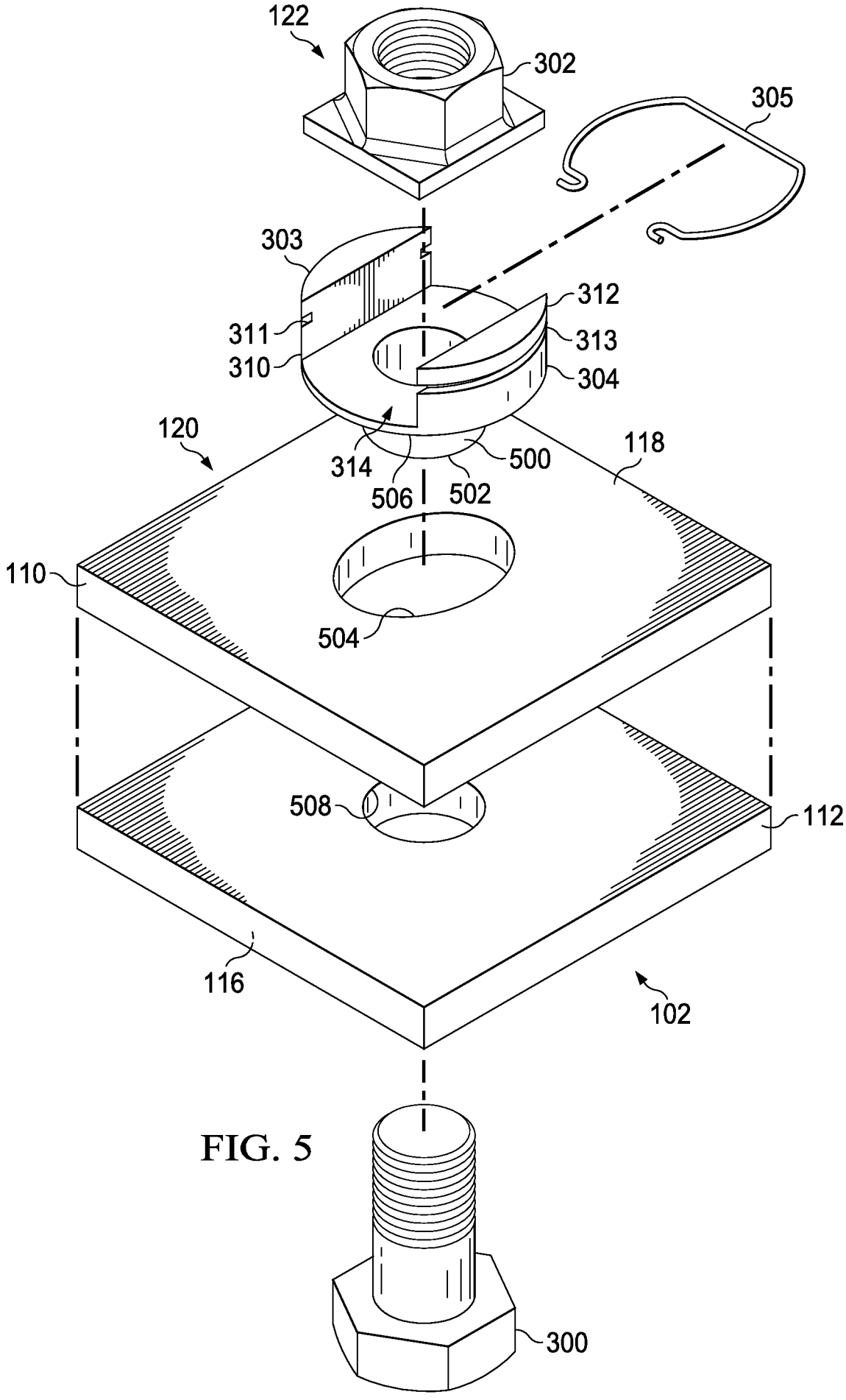

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FIG. 5

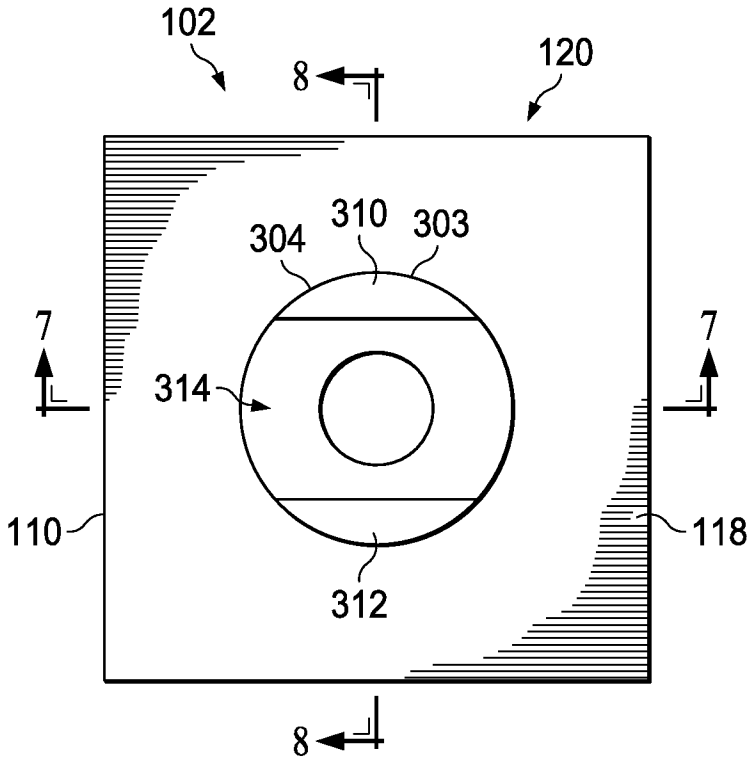

102
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FIG. 6

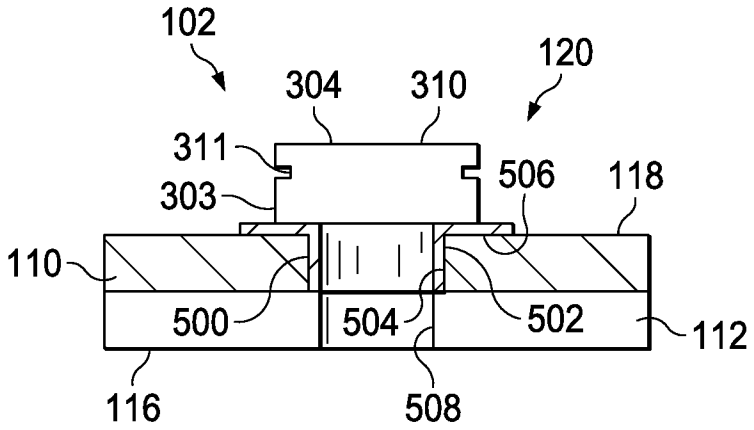

102
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FIG. 7

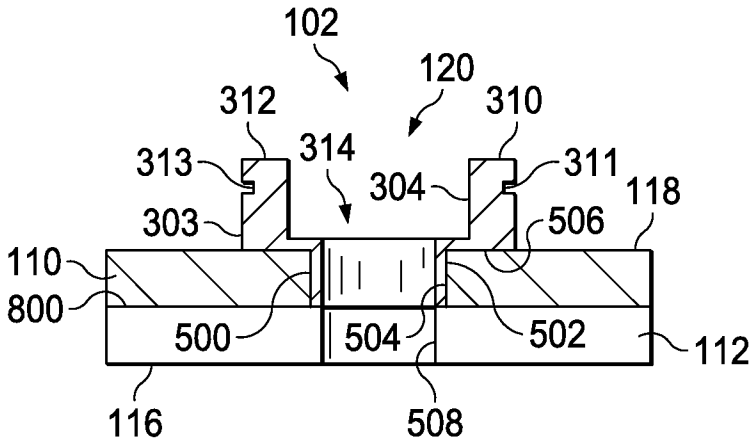

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FIG. 8

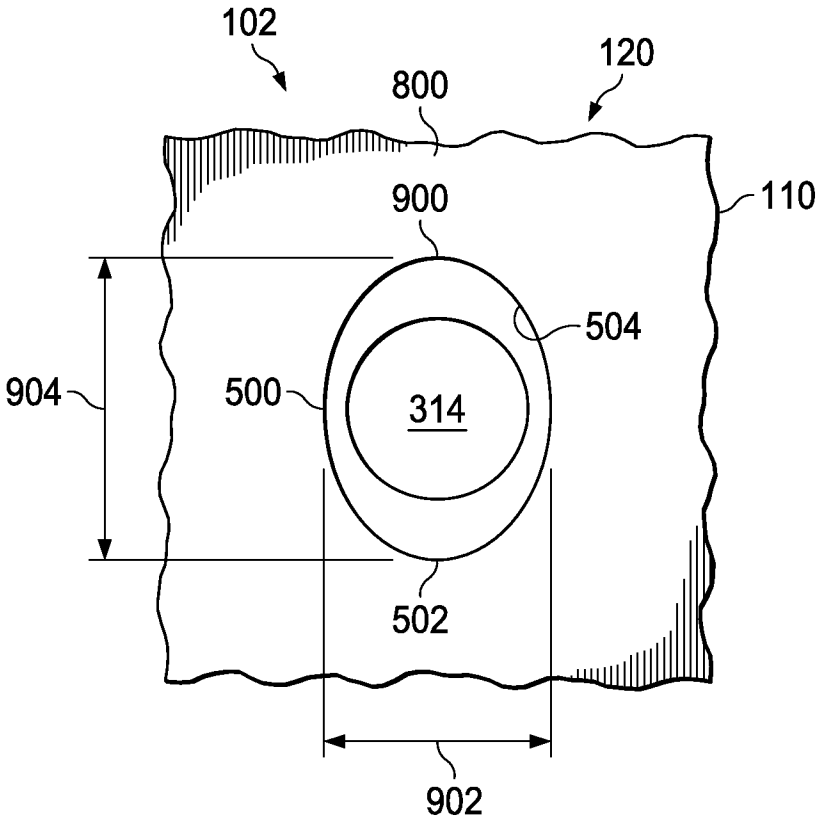

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800
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900
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904
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502
902

FIG. 9

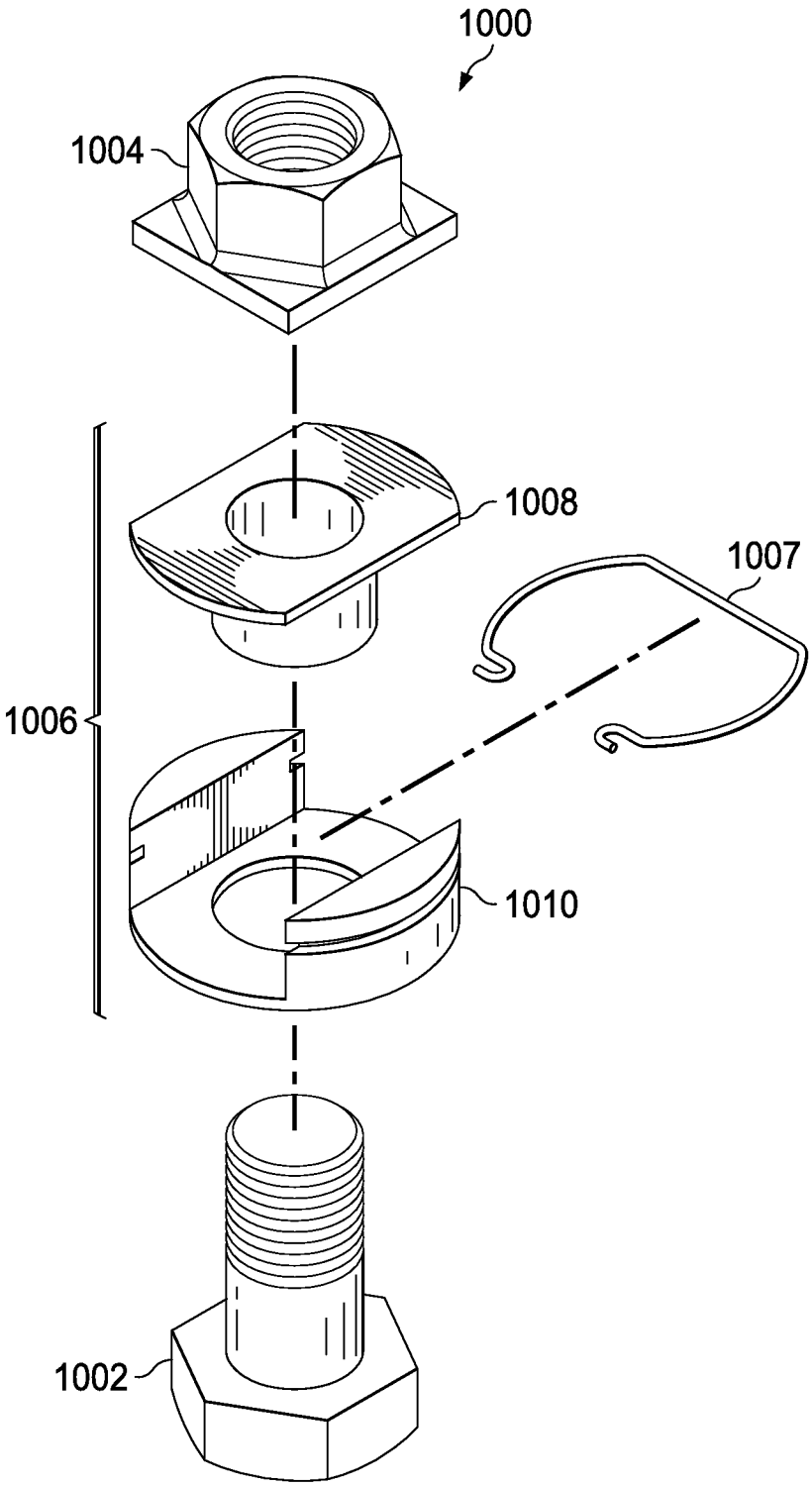


FIG. 10

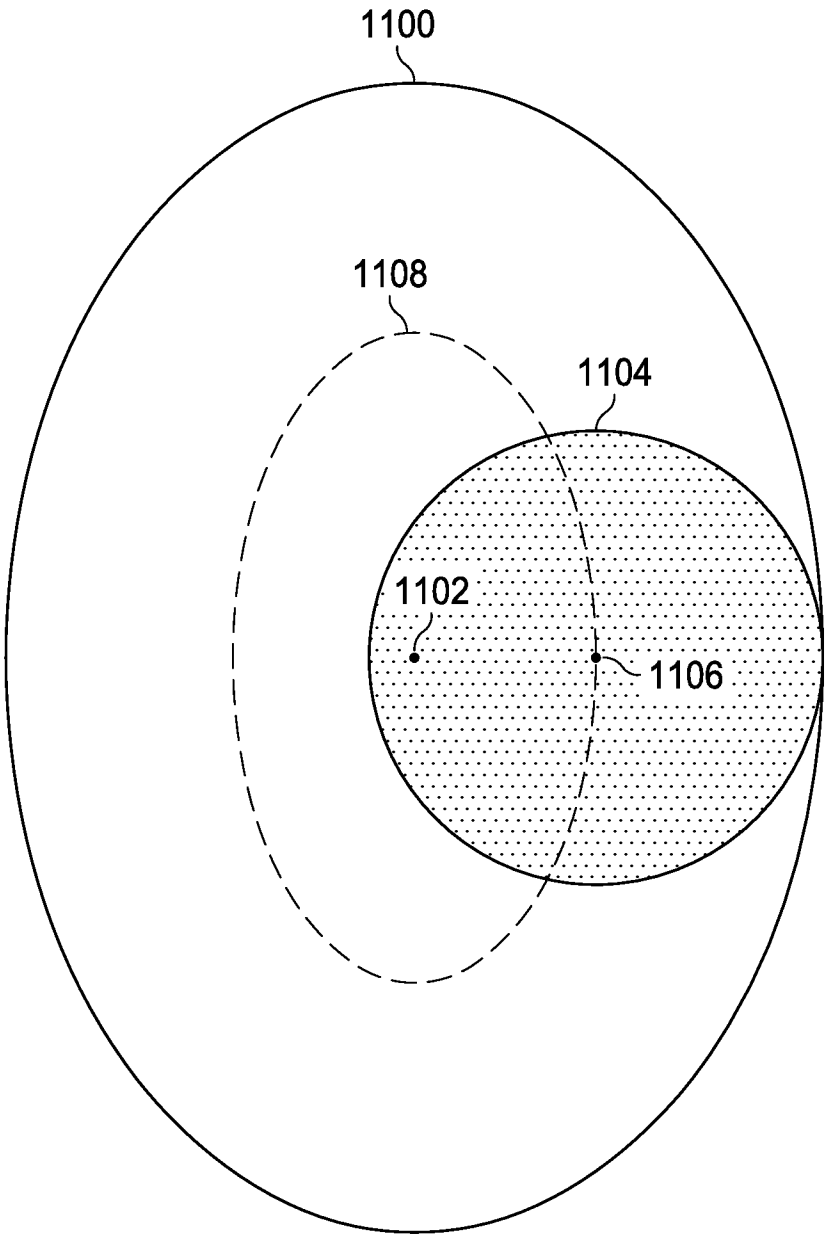


FIG. 11

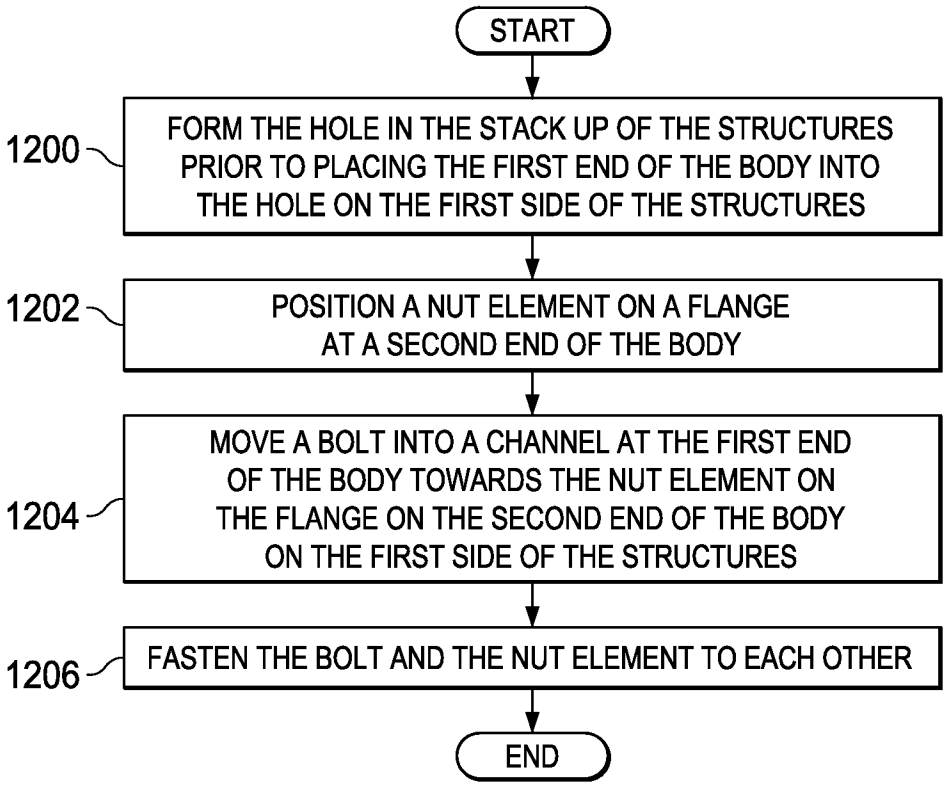

START
1200
FORM THE HOLE IN THE STACK UP OF THE STRUCTURES PRIOR TO PLACING THE FIRST END OF THE BODY INTO THE HOLE ON THE FIRST SIDE OF THE STRUCTURES
1202
POSITION A NUT ELEMENT ON A FLANGE AT A SECOND END OF THE BODY
1204
MOVE A BOLT INTO A CHANNEL AT THE FIRST END OF THE BODY TOWARDS THE NUT ELEMENT ON THE FLANGE ON THE SECOND END OF THE BODY ON THE FIRST SIDE OF THE STRUCTURES
1206
FASTEN THE BOLT AND THE NUT ELEMENT TO EACH OTHER
END

FIG. 12

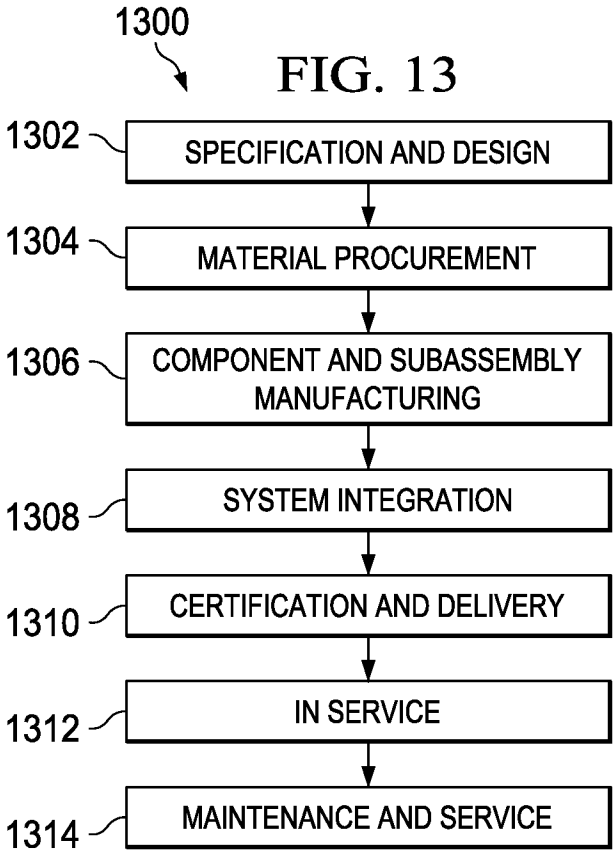

1300
1302
SPECIFICATION AND DESIGN
1304
MATERIAL PROCUREMENT
1306
COMPONENT AND SUBASSEMBLY MANUFACTURING
1308
SYSTEM INTEGRATION
1310
CERTIFICATION AND DELIVERY
1312
IN SERVICE
1314
MAINTENANCE AND SERVICE

FIG. 13

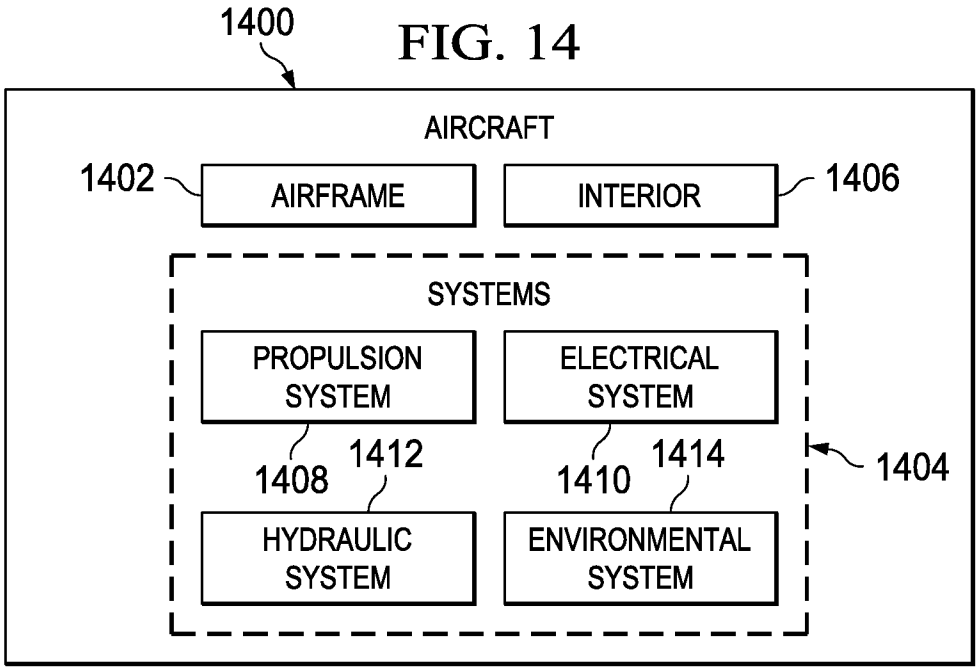

1400
AIRCRAFT
1402
AIRFRAME
INTERIOR
1406
SYSTEMS
PROPULSION SYSTEM
ELECTRICAL SYSTEM
1408
1412
1410
1414
1404
HYDRAULIC SYSTEM
ENVIRONMENTAL SYSTEM

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/011493

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16B37/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 0 530 132 A1 (VSI CORP [US]) 3 March 1993 (1993-03-03) column 7, line 37 - column 8, line 30 -----	1,3-12, 14 2,13,15
Y	FR 2 936 845 A1 (ALCOA FIXATIONS SIMMONDS SAS [FR]) 9 April 2010 (2010-04-09) page 10, line 21 - page 11, line 3 -----	2,13,15
A	EP 0 186 608 A1 (REXNORD INC [US]) 2 July 1986 (1986-07-02) the whole document -----	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 April 2014	02/05/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Rochus, Johann

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2014/011493

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