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(71) Applicant: **Rohr, Inc.**
Chula Vista, CA 91910-2098 (US)

(72) Inventor: **DOUGLAS, Alan R.**
Chula Vista, CA California 91910 (US)

(74) Representative: **Dehns**
St. Bride's House
10 Salisbury Square
London EC4Y 8JD (GB)

(54) METHOD AND ASSEMBLY FOR FORMING AN ANNULAR OBJECT

(57) A method is provided for forming an annular object. This method includes: providing a frustoconical preform (104) extending axially along an axis (28), wherein a sidewall of the frustoconical preform (104) is angularly offset from the axis (28) by a preform angle (120); externally drawing the frustoconical preform (104) over an outer surface (34) of a punch (22) and an outer surface (80) of a die clamp (72) to provide an externally drawn body (122), wherein the outer surface (80) of the die clamp (72) is angularly offset from the axis (28) by a die clamp angle (82) that is different than the preform angle (120); mating a die (74) with the die clamp (72) to provide a die assembly (26), wherein the externally drawn body (122) is clamped radially between the die (74) and the die clamp (72); and translating the die assembly (26) axially along the axis (28) and into a bore (38) of the punch (22) to at least partially internally draw the externally drawn body (122) against an inner surface (36) of the punch (22).

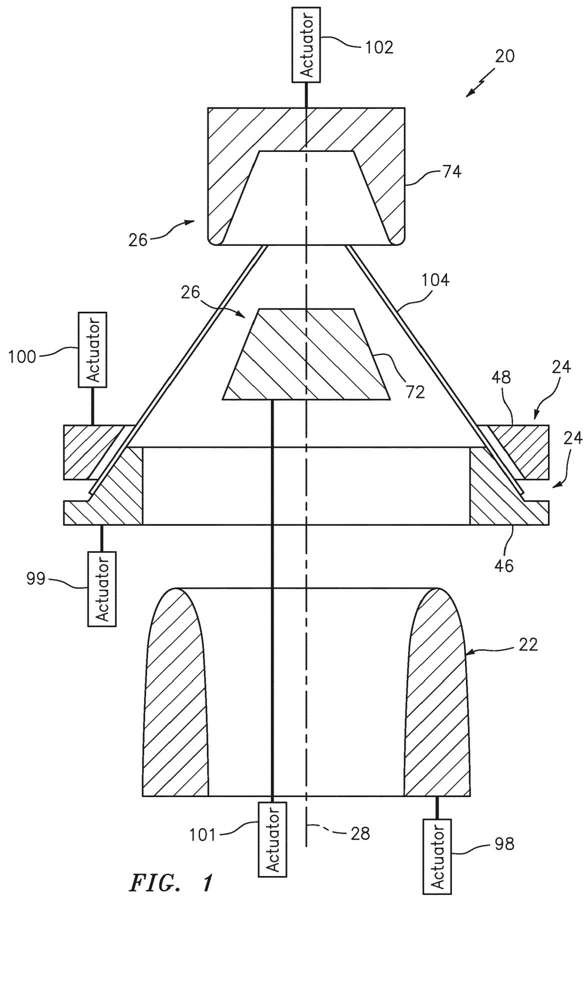

FIG. 1

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Description

BACKGROUND

1. Technical Field

[0001] This disclosure relates generally to methods and assemblies for forming an annular object.

2. Background Information

[0002] A modern aircraft propulsion system for an airplane such as a commercial airliner includes a nacelle for housing a gas turbine engine. The nacelle typically includes an inlet lip (e.g., a nose lip) at an upstream end of the nacelle. This inlet lip is provided to form an inlet for directing incoming air into the gas turbine engine. The inlet lip has an annular body, which is preferably formed from a single sheet of material. While various methods are known in the art for forming an inlet lip, there is still room in the art for improvement.

SUMMARY OF THE DISCLOSURE

[0003] According to an aspect of the present invention, a method is provided for forming an annular object. This method includes step of: providing a frustoconical preform extending axially along an axis, wherein a sidewall of the frustoconical preform is angularly offset from the axis by a preform angle; externally drawing the frustoconical preform over an outer surface of a punch and an outer surface of a die clamp to provide an externally drawn body, wherein the outer surface of the die clamp is angularly offset from the axis by a die clamp angle that is different than the preform angle; mating a die with the die clamp to provide a die assembly, wherein the externally drawn body is clamped radially between the die and the die clamp; and translating the die assembly axially along the axis and into a bore of the punch to at least partially internally draw the externally drawn body against an inner surface of the punch.

[0004] According to another aspect of the present invention, another method is provided for forming an annular object. This method includes step of: clamping a frustoconical preform with an external die assembly, wherein a surface of the external die assembly abutted against the frustoconical preform is angularly offset from an axis by an external die angle; translating the external die assembly axially along the axis to externally draw the frustoconical preform over an outer surface of a punch and an outer surface of an internal die clamp to provide an externally drawn body, wherein the outer surface of the internal die clamp is angularly offset from the axis by a die clamp angle that is different than the external die angle; mating an internal die with the internal die clamp to provide an internal die assembly, wherein the externally drawn body is clamped radially between the internal die and the internal die clamp; and translating the internal die assembly axially along the axis and into a bore of the punch to at least partially internally draw the externally drawn body against an inner surface of the punch.

[0005] According to still another aspect of the present invention, an assembly is provided for forming an annular object. This assembly includes a punch, an external die assembly and an internal die assembly, where the internal die assembly includes an internal die clamp and an internal die. The external die assembly is configured to clamp onto a frustoconical preform. The external die assembly is also configured to translate axially along an axis to externally draw the frustoconical preform over an outer surface of the punch and an outer surface of the internal die clamp to provide an externally drawn body. A surface of the external die assembly configured to contact the frustoconical preform is angularly offset from the axis by an external die angle. The outer surface of the internal die clamp is angularly offset from the axis by a die clamp angle that is different than the external die angle. The internal die is configured to mate with the internal die clamp such that the externally drawn body is clamped radially between the internal die and the internal die clamp. The internal die assembly is configured to translate axially along the axis and into a bore of the punch to at least partially internally draw the externally drawn body against an inner surface of the punch.

[0006] The following optional features may be applied to any of the above aspects.

[0007] The die clamp angle may be greater than fifteen degrees and less than twenty-five degrees. In addition or alternatively, the external die angle may be greater than twenty-five degrees and less than forty degrees.

[0008] The die clamp angle may be less than the preform angle.

[0009] The die clamp angle may be between fifteen degrees and twenty-five degrees.

[0010] The preform angle may be between twenty-five degrees and forty degrees.

[0011] The method may also include steps of: clamping the frustoconical preform with an external die assembly; and translating the external die assembly axially along the axis to at least partially externally draw the frustoconical preform over at least one of the outer surface of the punch or the outer surface of the die clamp.

[0012] The external die assembly may include an inner clamp member and an outer clamp member. The frustoconical preform may be clamped between an outer surface of the inner clamp member and an inner surface of the outer clamp member. The outer surface of the inner clamp member may be angularly offset from the axis by an external die angle that is different that the die clamp angle.

[0013] The external die angle may be equal to the preform angle.

[0014] The frustoconical preform may be configured from or otherwise include metal.

[0015] The annular object may be configured as or otherwise include an inlet lip of an aircraft propulsion system nacelle.

[0016] The method may also include a step of annealing the externally drawn body following the translating of the die assembly.

[0017] The die clamp angle may be less than the external die angle.

[0018] The die clamp angle may be greater than fifteen degrees and less than twenty-five degrees.

[0019] The external die angle may be greater than twenty-five degrees and less than forty degrees.

[0020] A sidewall of the frustoconical preform may be angularly offset from the axis by a preform angle. The die clamp angle may be different than the preform angle.

[0021] The external die assembly may include an inner clamp member and an outer clamp member. The surface of the external die assembly may be an outer surface of the inner clamp member. The frustoconical preform may be clamped between the outer surface of the inner clamp member and an inner surface of the outer clamp member.

[0022] The frustoconical preform may be formed from metal.

[0023] The annular object may be configured as an inlet structure of a nacelle for an aircraft propulsion system.

[0024] The foregoing features and the operation of the invention will become more apparent in light of the following description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

FIG. 1 is a sectional illustration of an assembly for forming an annular object, which assembly is schematically depicted with actuators.

FIG. 2 is a sectional illustration of a punch.

FIG. 3 is a sectional illustration of an external die assembly.

FIG. 4 is a sectional illustration of an internal die assembly.

FIG. 5 is a flow diagram of a method for forming an annular object.

FIG. 6 is a sectional illustration of a frustoconical preform.

FIG. 7 is a sectional illustration of the external die assembly clamped onto the frustoconical preform.

FIGS 8-11 are sectional illustration of the assembly of FIG. 1 at different stages during the formation of the annular object.

FIG. 12 is a side illustration of an aircraft propulsion system.

DETAILED DESCRIPTION

[0026] FIG. 1 illustrates an assembly 20 for forming an annular object. An example of the annular object is an inlet structure or an inlet lip of the inlet structure of a nacelle for an aircraft propulsion system, an exemplary embodiment of which is described below in further detail with respect to FIG. 12. The present disclosure, however, is not limited to the foregoing exemplary annular object configuration nor to aircraft propulsion system applications.

[0027] The formation assembly 20 of FIG. 1 includes a punch 22, an external die assembly 24 and an internal die assembly 26. The formation assembly 20 may also include an actuation system configured to move (e.g., translate) one or more of the formation assembly components 22, 24, 26 along an axis 28; e.g., an axial centerline of the formation assembly 20 and/or the annular object to be formed.

[0028] The punch 22 is configured as a tubular body. The punch 22 of FIG. 2, for example, extends circumferentially about (e.g., completely around) the axis 28 so as to form a full hoop punch body. The punch 22 extends axially along the axis 28 from a punch first (e.g., base) end 30 to a punch second (e.g., distal) end 32. The punch 22 extends radially between a (e.g., tubular) punch outer surface 34 and a (e.g., tubular) punch inner surface 36. The punch inner surface 36 forms a punch bore 38 in the punch 22, which punch bore 38 extends axially along the axis 28 at least partially into or through the punch 22 from the punch second end 32 towards or to the punch first end 30.

[0029] The punch outer and inner surfaces 34 and 36 may meet and may be joined together at a (e.g., annular) blunt, curved and/or otherwise eased edge 40 of the punch 22 at the punch second end 32. The punch inner surface 36 and the punch outer surface 34 may each be shaped to substantially follow a finished geometry of the annular object to be formed. The punch outer and inner surfaces 34 and 36 of FIG. 2 are shaped such that a radial width 42 of at least a portion (e.g., axial length), or an entirety of, a sidewall 44 of the punch 22 radially tapers as the punch 22 extends axially along the axis 28 to the punch second end 32.

[0030] Referring to FIG. 3, the external die assembly 24 includes an inner clamp member 46 and an outer clamp member 48.

[0031] The inner clamp member 46 is configured as an annular body with a base 50 and a flange 52; e.g., an annular rim. The inner clamp member 46 of FIG. 3, for example, extends circumferentially about (e.g., completely around) the axis 28 so as to form a full hoop inner clamp member body. The inner clamp member 46 extends axially along the axis 28 from an inner clamp member first end 54 to an inner clamp member second end 56. The base 50 of the inner clamp member 46 extends radially between an inner clamp member inner surface 58 and an inner clamp member outer surface 60. The inner clamp member outer surface 60 of FIG. 3 has a frustoconical geometry. The inner clamp member outer surface 60 of FIG. 3, for example, tapers radially inward as that surface 60 extends axially along the axis 28 to the inner clamp member second end 56.

[0032] The inner clamp member outer surface 60 is angularly offset from the axis 28 by an inner clamp member angle 62; e.g., an external die angle. This inner clamp member angle 62 may be an acute angle. The inner clamp member angle 62, for example, may be greater than (or equal to) twenty-five degrees (25°) and less than (or equal to) forty degrees (40°); e.g., the angle 62 may be equal to thirty degrees (30°).

[0033] The flange 52 is located at the inner clamp member first end 54. The flange 52 projects radially out from the base 50 and may be axially adjacent an edge of the inner clamp member outer surface 60.

[0034] The outer clamp member 48 is configured as an annular body. The outer clamp member 48 of FIG. 3, for example, extends circumferentially about (e.g., completely around) the axis 28 so as to form a full hoop outer clamp member body. The outer clamp member 48 extends axially along the axis 28 from an outer clamp member first end 64 to an outer clamp member second end 66. The outer clamp member 48 extends radially between an outer clamp member inner surface 68 and an outer clamp member outer surface 70. The outer clamp member inner surface 68 of FIG. 3 has a frustoconical geometry. The outer clamp member inner surface 68 is shaped and dimensioned to compliment (e.g., substantially mirror) the geometry of the inner clamp member outer surface 60. The outer clamp member inner surface 68 may thereby engage the inner clamp member outer surface 60 as described below in further detail.

[0035] Referring to FIG. 4, the internal die assembly 26 includes an internal die clamp 72 and an internal die 74.

[0036] The internal die clamp 72 extends axially along the axis 28 from a die clamp first end 76 to a die clamp second end 78. The internal die clamp 72 extends radially outward to a die clamp outer surface 80. This die clamp outer surface 80 extends circumferentially about (e.g., completely around) the axis 28. The die clamp outer surface 80 of FIG. 4 has a frustoconical geometry. The die clamp outer surface 80 of FIG. 4, for example, tapers radially inward as that surface 80 extends axially along the axis 28 from the die clamp first end 76 to the die clamp second end 78.

[0037] The die clamp outer surface 80 is angularly offset from the axis 28 by a die clamp angle 82. This die clamp angle 82 may be an acute angle. The die clamp angle 82 is different (e.g., less) than the inner clamp member angle 62 (see FIG. 3). The die clamp angle 82, for example, may be greater than (or equal to) fifteen degrees (15°) and less than (or equal to) twenty-five degrees (25°); e.g., the angle 82 may be equal to twenty degrees (20°).

[0038] The internal die 74 may have a generally cup-shaped body; e.g., a body with a generally U or V shaped cross-sectional geometry. The internal die 74 of FIG. 4, for example, includes a tubular rim 84 and a base 86; e.g., an end cap / base plate.

[0039] The tubular rim 84 extends circumferentially about (e.g., completely around) the axis 28. The tubular rim 84 extends axially along the axis 28 from an internal die first end 88 to the base 86, which is disposed at an internal die second end 90. The tubular rim 84 extends radially between an internal die outer surface 92 and an internal die inner surface 94. The internal die inner surface 94 forms an aperture 96 (e.g., an indentation, pocket, etc.) in the internal die 74, which aperture 96 extends (e.g., partially) into the internal die 74 from the internal die first end 88 to the base 86. The internal die inner surface 94 of FIG. 4 has a frustoconical geometry. The internal die inner surface 94 is shaped and dimensioned to compliment (e.g., substantially mirror) the geometry of the die clamp outer surface 80. The internal die inner surface 94 may thereby engage the die clamp outer surface 80 as described below in further detail.

[0040] The actuation system of FIG. 1 includes one or more actuators 98-102; e.g., linear actuators. Each of these actuators 98-102 is configured to hold and/or axially translate a respective one of the formation assembly components 22, 46, 48, 72, 74 along the axis 28. Each actuator 98-102 may by hydraulically, pneumatically and/or electromechanically driven.

[0041] FIG. 5 is a flow diagram of a method 500 for forming the annular object. This method 500 is described below with reference to the formation assembly 20 of FIG. 1. However, the method 500 is not limited to using the exemplary formation assembly described above.

[0042] In step 502, a frustoconical preform 104 is provided as shown, for example, in FIG. 6. This frustoconical preform 104 may be constructed from sheet material. The frustoconical preform 104, for example, may be constructed from a sheet of metal; e.g., sheet metal. Examples of the metal include, but are not limited to, aluminum (Al), titanium (Ti), or an alloy one or more of the foregoing metals.

[0043] The frustoconical preform 104 of FIG. 6 is configured as a tubular body. The frustoconical preform 104 of FIG. 6, for example, extends circumferentially about (e.g., completely around) the axis 28 so as to form a full hoop preform body. The frustoconical preform 104 extends axially along the axis 28 from a preform first end 106 to a preform second end 108. The frustoconical preform 104 extends radially between a preform outer surface 110 and a preform inner surface 112. The preform inner surface 112 forms a preform bore 114 in the frustoconical preform 104, which preform bore 114 extends axially along the axis 28 through the frustoconical preform 104 from the preform first end 106 to the preform second end 108.

[0044] The frustoconical preform 104 and its surfaces 110 and 112 taper radially inwards as each of those elements 104, 110, 112 extends from the preform first end 106 to the preform second end 108. Thus, a diameter 116 of the frustoconical preform 104 at the preform first end 106 is greater than a diameter 118 of the frustoconical preform 104 at the preform second end 108.

[0045] One or more or each preform element 104, 110, 112 may be angularly offset from the axis 28 by a preform angle 120. This preform angle 120 may be an acute angle. The preform angle 120 may be equal to the inner clamp member angle 62 (see FIG. 3); e.g., the external die angle. The preform angle 120 is different (e.g., greater) than the die clamp angle 82 (see FIG. 4). The preform angle 120, for example, may be greater than (or equal to) twenty-five degrees (25°) and less than (or equal to) forty degrees (40°); e.g., the angle 120 may be equal to thirty degrees (30°).

[0046] In step 504, the frustoconical preform 104 is clamped with (e.g., by) the external die assembly 24 as shown, for example, in FIG. 7. A portion of the frustoconical preform 104 at (e.g., on, adjacent or proximate) the preform first end 106, for example, is clamped between the inner clamp member outer surface 60 and the outer clamp member inner surface 68. More particularly, the base 50 of the inner clamp member 46 may be inserted into the preform bore 114 such that the inner clamp member outer surface 60 radially engages (e.g., contacts) the preform inner surface 112 at the preform first end 106. The outer clamp member 48 may then be translated axially along the axis 28 until the outer clamp member inner surface 68 radially engages (e.g., contacts) the preform outer surface 110 at the preform first end 106. The frustoconical preform 104 may thereby be clamped radially between the clamp members 46 and 48.

[0047] In step 506, the frustoconical preform 104 is externally drawn to provide an externally drawn object 122 (see FIG. 9) as shown, for example, in the sequence of FIGS. 8 and 9. For example, the external die assembly 24, which is clamped onto the frustoconical preform 104, is translated axially along the axis 28 to draw the frustoconical preform 104 onto the punch outer surface 34 and/or the die clamp outer surface 80. The external die assembly 24, in other words, pulls the frustoconical preform 104 over and shapes the frustoconical preform 104 to the punch outer surface 34 and/or the die clamp outer surface 80. The portion of the frustoconical preform 104 drawn onto / over the punch outer surface 34 may substantially take the shape and dimensions of an outer portion of the finished annular object. The portion of the frustoconical preform 104 drawn onto / over the die clamp outer surface 80 is reshaped to increase the diameter 118 at the second end 108; e.g., the diameter 118 at the stage in FIG. 9 is greater than the diameter 118 at the stage in FIG. 8.

[0048] The drawing of the frustoconical preform 104 onto the punch 22 may be performed simultaneously with the drawing of the frustoconical preform 104 onto the die clamp 72. The method 500 of the present disclosure, however, is not limited to such a simultaneous drawing. For example, in other embodiments, the frustoconical preform 104 may be partially or completely drawn onto the die clamp 72 before the drawing of the frustoconical preform 104 onto the punch 22, or vice versa.

[0049] In some embodiments, the translation of the external die assembly 24 may partially draw the frustoconical preform 104 onto the die clamp outer surface 80. The drawing of the frustoconical preform 104 onto the die clamp outer surface 80 may subsequently be completed by mating the internal die 74 with the internal die clamp 72.

[0050] In step 508, the internal die 74 is mated with the internal die clamp 72 to clamp the externally drawn object 122 as shown, for example, in FIG. 10. A portion of the externally drawn object 122 at (e.g., on, adjacent or proximate) the preform second end 108, for example, is clamped between the die clamp outer surface 80 and the internal die inner surface 94. More particularly, the internal die 74 may be translated axially along the axis 28 until the internal die inner surface 94 radially engages (e.g., contacts) the outer surface 110 at the second end 108. The externally drawn object 122 may thereby be clamped radially between the internal die clamp 72 and the internal die 74.

[0051] In step 510, the externally drawn object 122 is at least partially (or completely) internally drawn to provide an annular body 124 (see FIG. 11) as shown, for example, in the sequence of FIGS. 10 and 11. For example, the internal die assembly 26, which is clamped onto the externally drawn object 122, is translated axially along the axis 28 into the punch bore 38 to at least partially (or completely) draw the externally drawn object 122 against the punch inner surface 36. The internal die assembly 26, in other words, pulls the externally drawn object 122 along and shapes the externally drawn object 122 to the punch inner surface 36. The portion of the externally drawn object 122 drawn against the punch inner surface 36 may substantially take the shape and dimensions of an inner portion of the finished annular object.

[0052] It is worth noting, by increasing the diameter 118 (see FIGS. 8-9) at the second end 108 in step 506, the distance of radial movement of the object's material is reduced when pressed against the punch inner surface 36. This in turn may reduce defects in the object's material such as, but not limited to, cracks and wrinkles. In addition, the internal drawing may be performed without intermediate annealing step(s), or with a reduced number of intermediate annealing step(s).

[0053] In step 512, the annular body 124 is heat treated. This heat treatment may be preformed while the annular body 124 is configured with the formation assembly 20. Alternatively, the heat treatment may be performed after the annular body 124 is removed from the formation assembly 20.

[0054] In step 514, the annular body 124 is trimmed to provide the finished annular object. For example, portions (e.g., see 126 and 128 in FIG. 11) of the annular body 124 which were used for clamping may be cut off.

[0055] The method 500, of course, may include one or more additional steps other than those discussed above. For example, the internal drawing of the externally drawn object 122 may be performed iteratively and, between iterations, the object's material may be annealed or otherwise heat treated. In another example, one or more additional finishing operations (e.g., polishing, etc.) may be performed before or after the trimming step 514. The method 500 of the present disclosure, therefore, is not limited to the exemplary steps nor particular sequence of performing the exemplary steps described above.

[0056] FIG. 12 illustrates an aircraft propulsion system 130 for an aircraft such as, but not limited to, a commercial airliner or a cargo plane. The propulsion system 130 includes a nacelle 132 and a gas turbine engine. This gas turbine engine may be configured as a high-bypass turbofan engine. Alternatively, the gas turbine engine may be configured as any other type of gas turbine engine capable of propelling the aircraft during flight.

[0057] The nacelle 132 is configured to house and provide an aerodynamic cover for the gas turbine engine. An outer nacelle structure 134 of the nacelle 132 extends along an axial centerline 136 of the gas turbine engine between a nacelle forward end 138 and a nacelle aft end 140, which centerline 136 may be coaxial with the axis 28. The nacelle structure 134 of FIG. 12 includes a nacelle inlet structure 142, one or more fan cowls 144 (one such cowl visible in FIG. 12) and a nacelle aft structure 146, which may be configured as part of or include a thrust reverser system 148. The annular object formed with the assembly 20 of FIG. 1 and/or the method 500 of FIG. 5 may be configured as a portion of, an entirety of or otherwise include the inlet structure 142. The annular object, for example, may be configured as an inlet lip 150 (e.g., a nose lip) of the inlet structure 142.

[0058] While various embodiments of the present invention have been disclosed, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible within the scope of the invention. For example, the present invention as described herein includes several aspects and embodiments that include particular features. Although these features may be described individually, it is within the scope of the present invention that some or all of these features may be combined with any one of the aspects and remain within the scope of the invention. Accordingly, the present invention is not to be restricted except in light of the attached claims and their equivalents.

Claims

1. A method for forming an annular object, comprising:

    providing a frustoconical preform (104) extending axially along an axis (28), wherein a sidewall of the frustoconical preform (104) is angularly offset from the axis (28) by a preform angle (120);
    externally drawing the frustoconical preform (104) over an outer surface (34) of a punch (22) and an outer surface (80) of a die clamp (72) to provide an externally drawn body (122), wherein the outer surface (80) of the die clamp (72) is angularly offset from the axis (28) by a die clamp angle (82) that is different than the preform angle (120);
    mating a die (74) with the die clamp (72) to provide a die assembly (26), wherein the externally drawn body (122) is clamped radially between the die (74) and the die clamp (72); and
    translating the die assembly (26) axially along the axis (28) and into a bore (38) of the punch (22) to at least partially internally draw the externally drawn body (122) against an inner surface (36) of the punch (22).

2. The method of claim 1, wherein:

    the die clamp angle (82) is less than the preform angle (120); and/or
    the die clamp angle (82) is between fifteen degrees and twenty-five degrees; and/or
    the preform angle (120) is between twenty-five degrees and forty degrees.

3. The method of claim 1 or 2, further comprising:

    clamping the frustoconical preform (104) with an external die assembly (24); and
    translating the external die assembly (24) axially along the axis (28) to at least partially externally draw the frustoconical preform (104) over at least one of the outer surface (34) of the punch (22) or the outer surface (80) of the die clamp (72).

4. The method of claim 3, wherein
    the external die assembly (24) includes an inner clamp member (46) and an outer clamp member (48);
    the frustoconical preform (104) is clamped between an outer surface (60) of the inner clamp member (46) and an inner surface (68) of the outer clamp member (48); and
    the outer surface (60) of the inner clamp member (46) is angularly offset from the axis (28) by an external die angle (62) that is different that the die clamp angle (82).

5. The method of claim 4, wherein the external die angle (62) is equal to the preform angle (120).

6. The method of any preceding claim, wherein the frustoconical preform (104) comprises metal.

7. The method of any preceding claim, wherein the annular object comprises an inlet lip (150) of an aircraft propulsion system nacelle (132).

8. The method of any preceding claim, further comprising annealing the externally drawn body (122) fol-

lowing the translating of the die assembly (26).

9. A method for forming an annular object, comprising:

clamping a frustoconical preform (104) with an external die assembly (24), wherein the frustoconical preform (104) is optionally formed from metal, and a surface of the external die assembly (24) abutted against the frustoconical preform (104) is angularly offset from an axis (28) by an external die angle (62);
translating the external die assembly (24) axially along the axis (28) to externally draw the frustoconical preform (104) over an outer surface (34) of a punch (22) and an outer surface (80) of an internal die clamp (72) to provide an externally drawn body (122), wherein the outer surface (80) of the internal die clamp (72) is angularly offset from the axis (28) by a die clamp angle (82) that is different than the external die angle (62);
mating an internal die (74) with the internal die clamp (72) to provide an internal die assembly (26), wherein the externally drawn body (122) is clamped radially between the internal die (74) and the internal die clamp (72); and
translating the internal die assembly (26) axially along the axis (28) and into a bore (38) of the punch (22) to at least partially internally draw the externally drawn body (122) against an inner surface (36) of the punch (22).

10. The method of claim 9, wherein:

the die clamp angle (82) is less than the external die angle (62); and/or
the die clamp angle (82) is greater than fifteen degrees and less than twenty-five degrees; and/or
the external die angle (62) is greater than twenty-five degrees and less than forty degrees.

11. The method of claim 9 or 10, wherein a sidewall of the frustoconical preform (104) is angularly offset from the axis (28) by a preform angle (120), and the die clamp angle (82) is different than the preform angle (120).

12. The method of claim 9, 10, or 11, wherein
the external die assembly (24) includes an inner clamp member (46) and an outer clamp member (48);
the surface of the external die assembly (24) is an outer surface (60) of the inner clamp member (46); and
the frustoconical preform (104) is clamped between the outer surface (60) of the inner clamp member (46) and an inner surface (68) of the outer clamp member (48).

13. The method of any of claims 9 to 12, wherein the annular object is configured as an inlet structure (142) of a nacelle (132) for an aircraft propulsion system (130).

14. An assembly (20) for forming an annular object, comprising:

a punch (22), an external die assembly (24) and an internal die assembly (26) that comprises an internal die clamp (72) and an internal die (74);
the external die assembly (24) configured to clamp onto a frustoconical preform (104), and the external die assembly (24) further configured to translate axially along an axis (28) to externally draw the frustoconical preform (104) over an outer surface (34) of the punch (22) and an outer surface (80) of the internal die clamp (72) to provide an externally drawn body (122), wherein a surface of the external die assembly (24) configured to contact the frustoconical preform (104) is angularly offset from the axis (28) by an external die angle (62), and the outer surface (80) of the internal die clamp (72) is angularly offset from the axis (28) by a die clamp angle (82) that is different than the external die angle (62);
the internal die (74) configured to mate with the internal die clamp (72) such that the externally drawn body (122) is clamped radially between the internal die (74) and the internal die clamp (72); and
the internal die assembly (26) configured to translate axially along the axis (28) and into a bore (38) of the punch (22) to at least partially internally draw the externally drawn body (122) against an inner surface (36) of the punch (22).

15. The assembly (20) of claim 14, wherein
the die clamp angle (82) is greater than fifteen degrees and less than twenty-five degrees; and
the external die angle (62) is greater than twenty-five degrees and less than forty degrees.

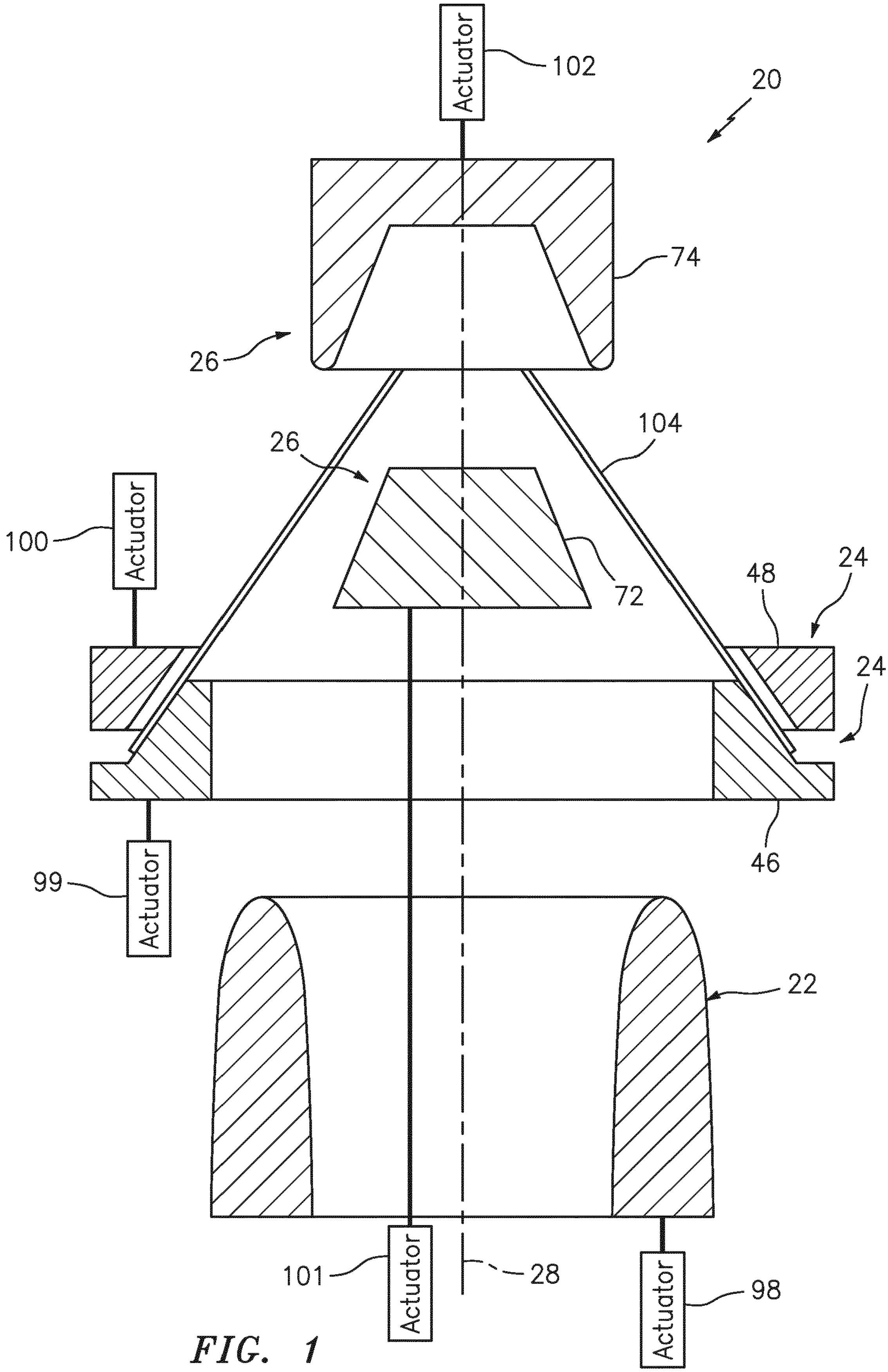
Actuator
102
20
74
26
26
104
72
Actuator
100
48
24
24
46
Actuator
99
22
101
Actuator
28
Actuator
98

FIG. 1

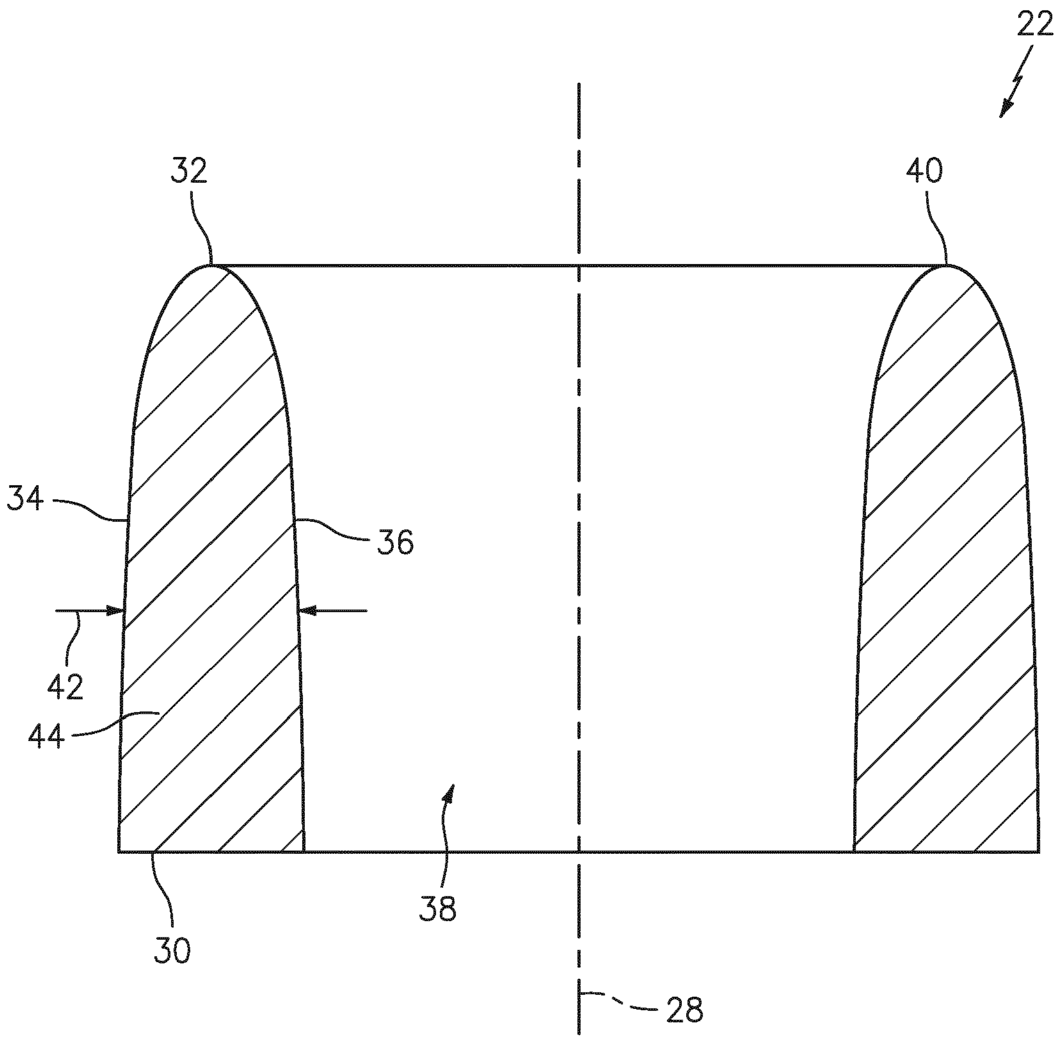

FIG. 2

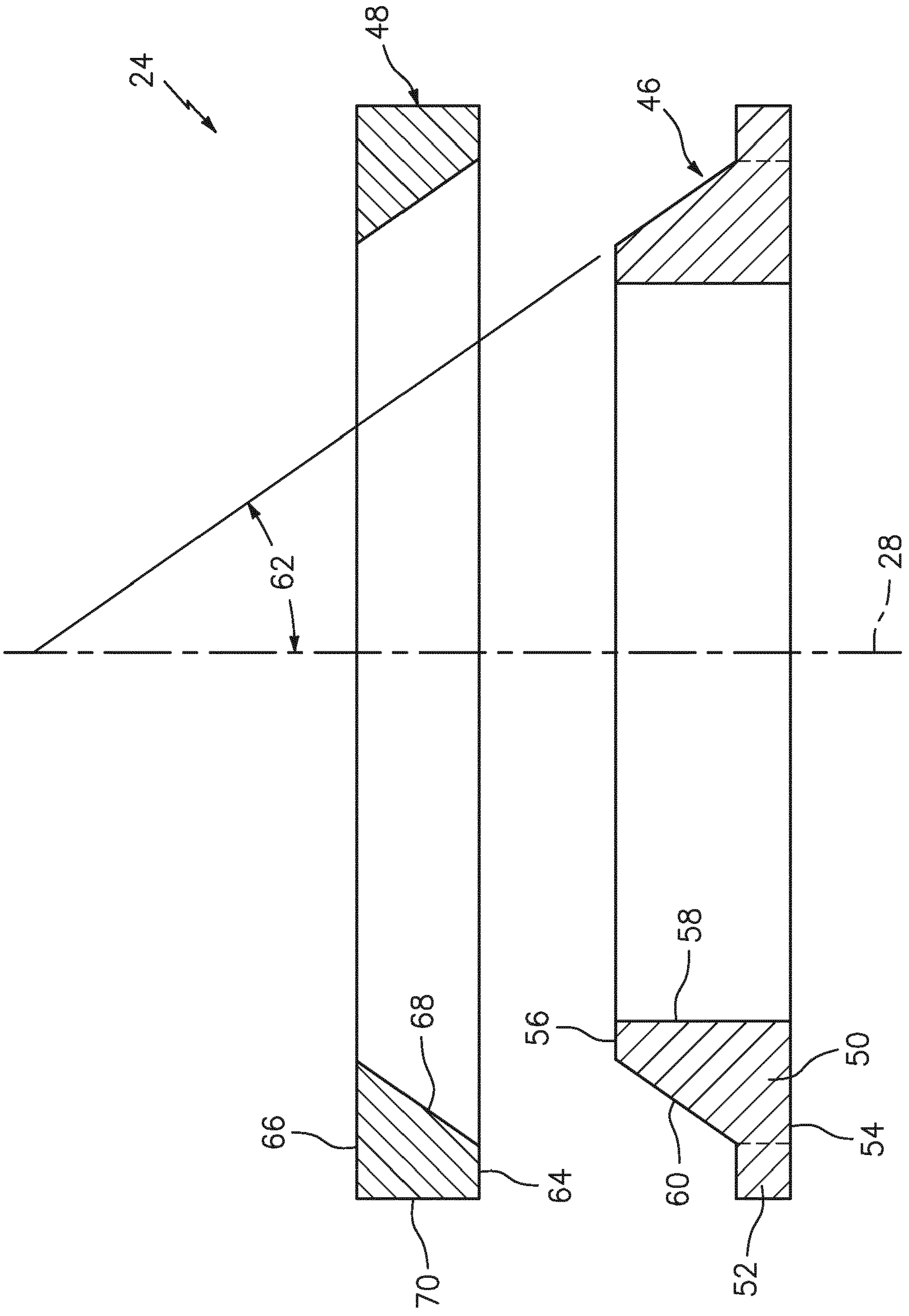

FIG. 3

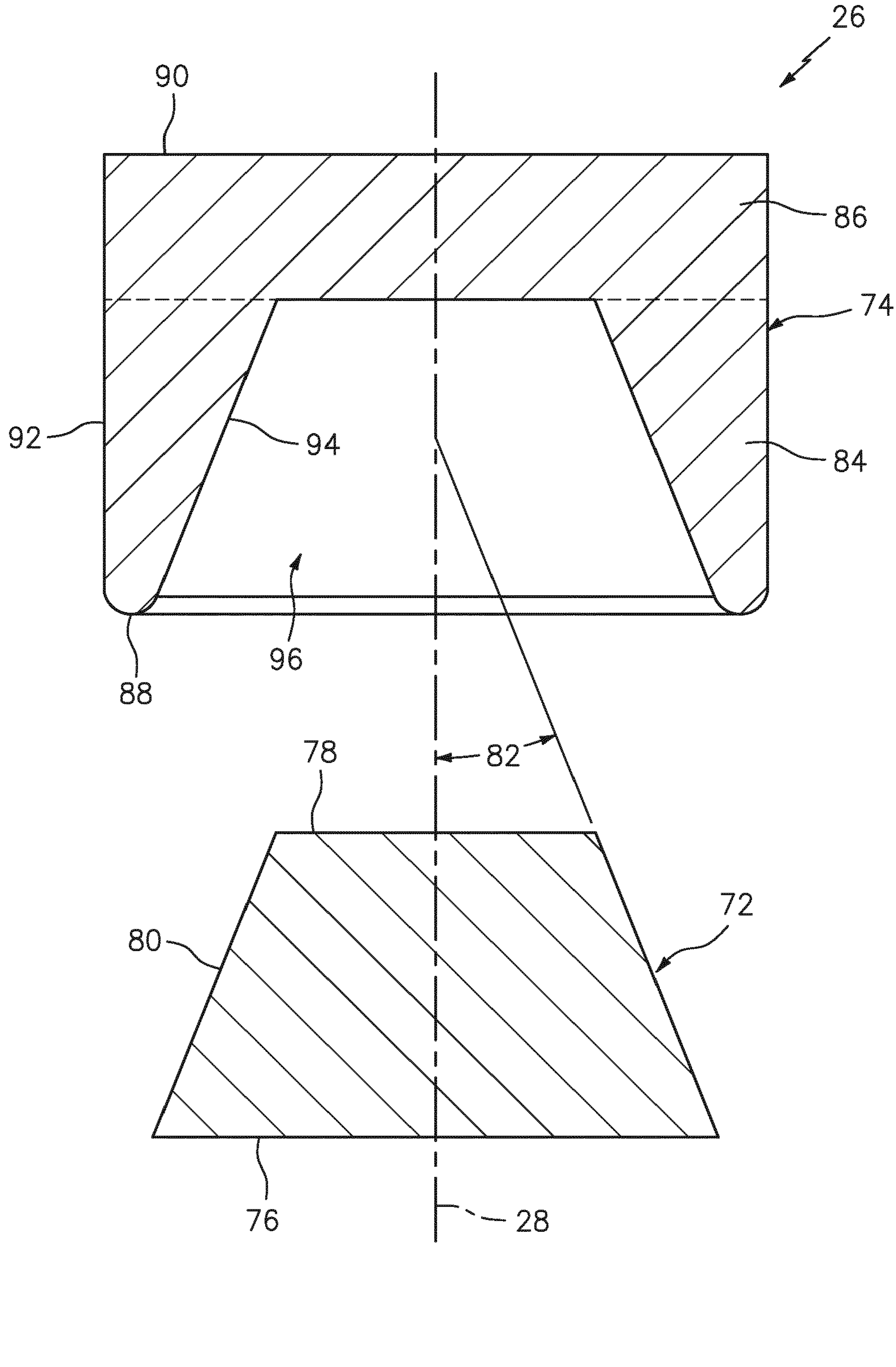

FIG. 4

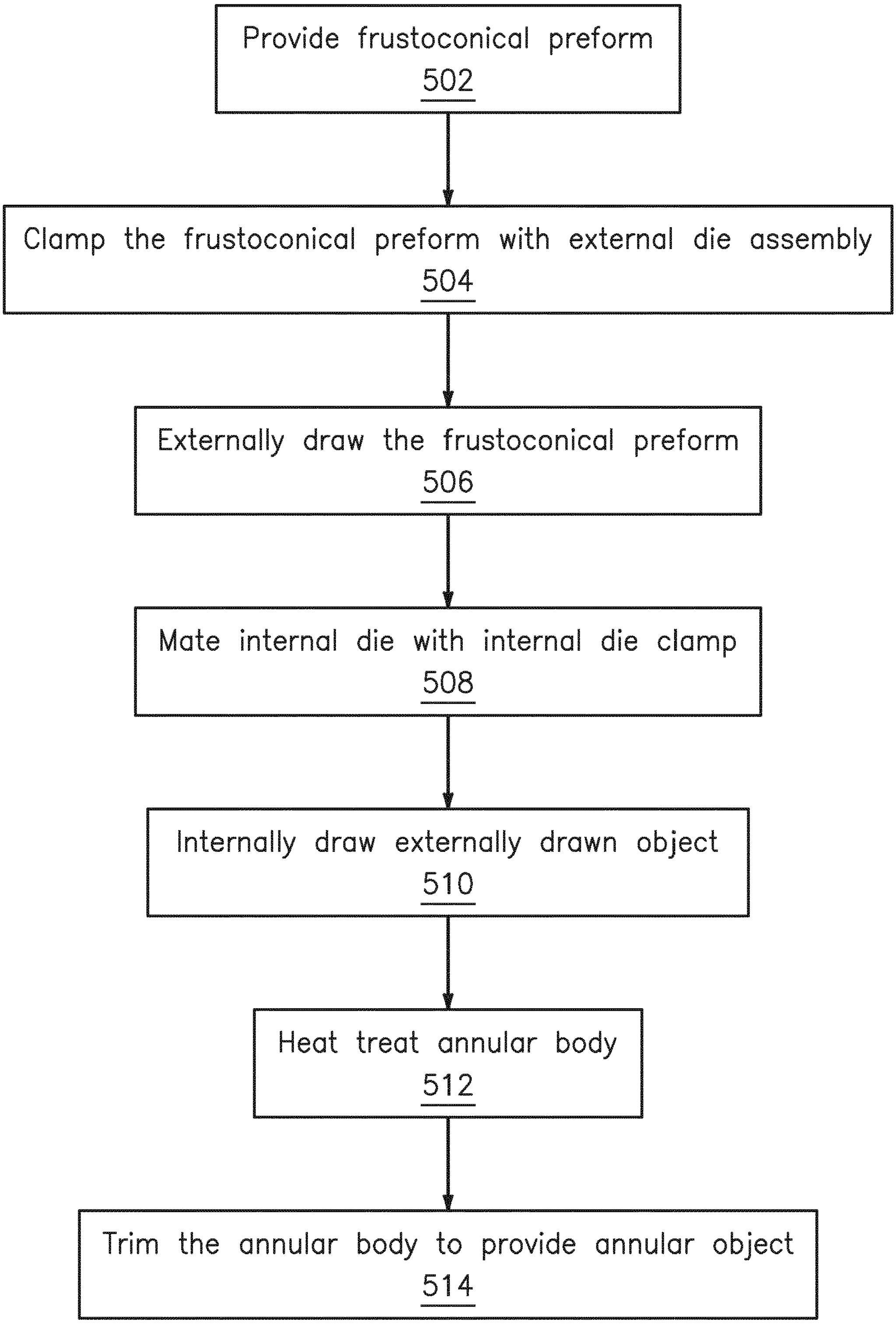
Provide frustoconical preform
502
Clamp the frustoconical preform with external die assembly
504
Externally draw the frustoconical preform
506
Mate internal die with internal die clamp
508
Internally draw externally drawn object
510
Heat treat annular body
512
Trim the annular body to provide annular object
514

FIG. 5

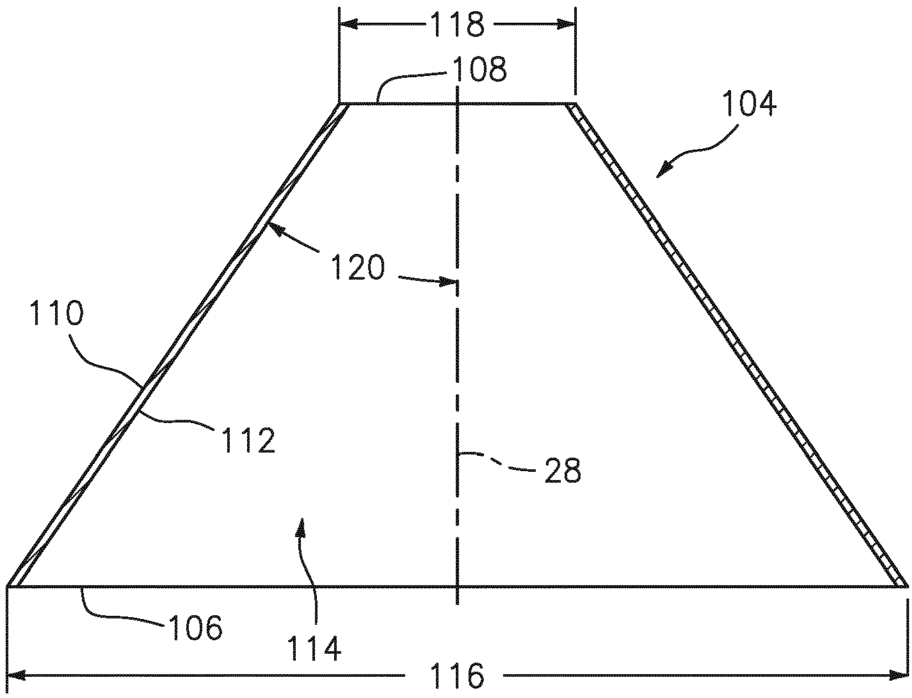

FIG. 6

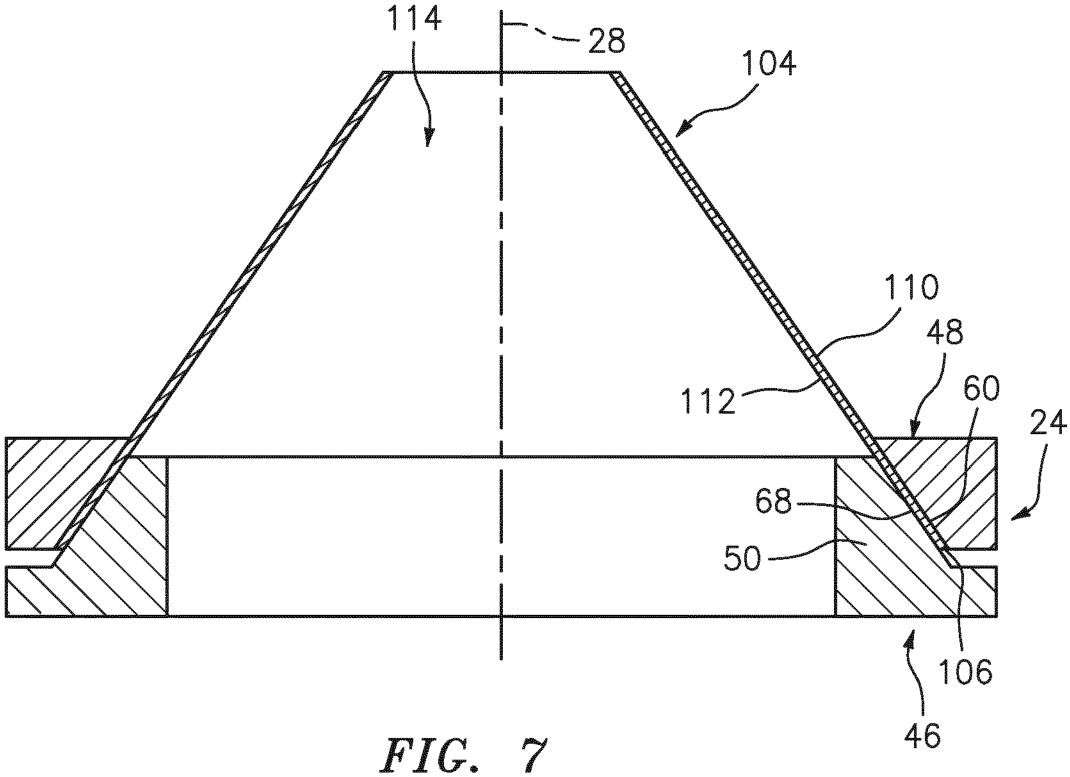

FIG. 7

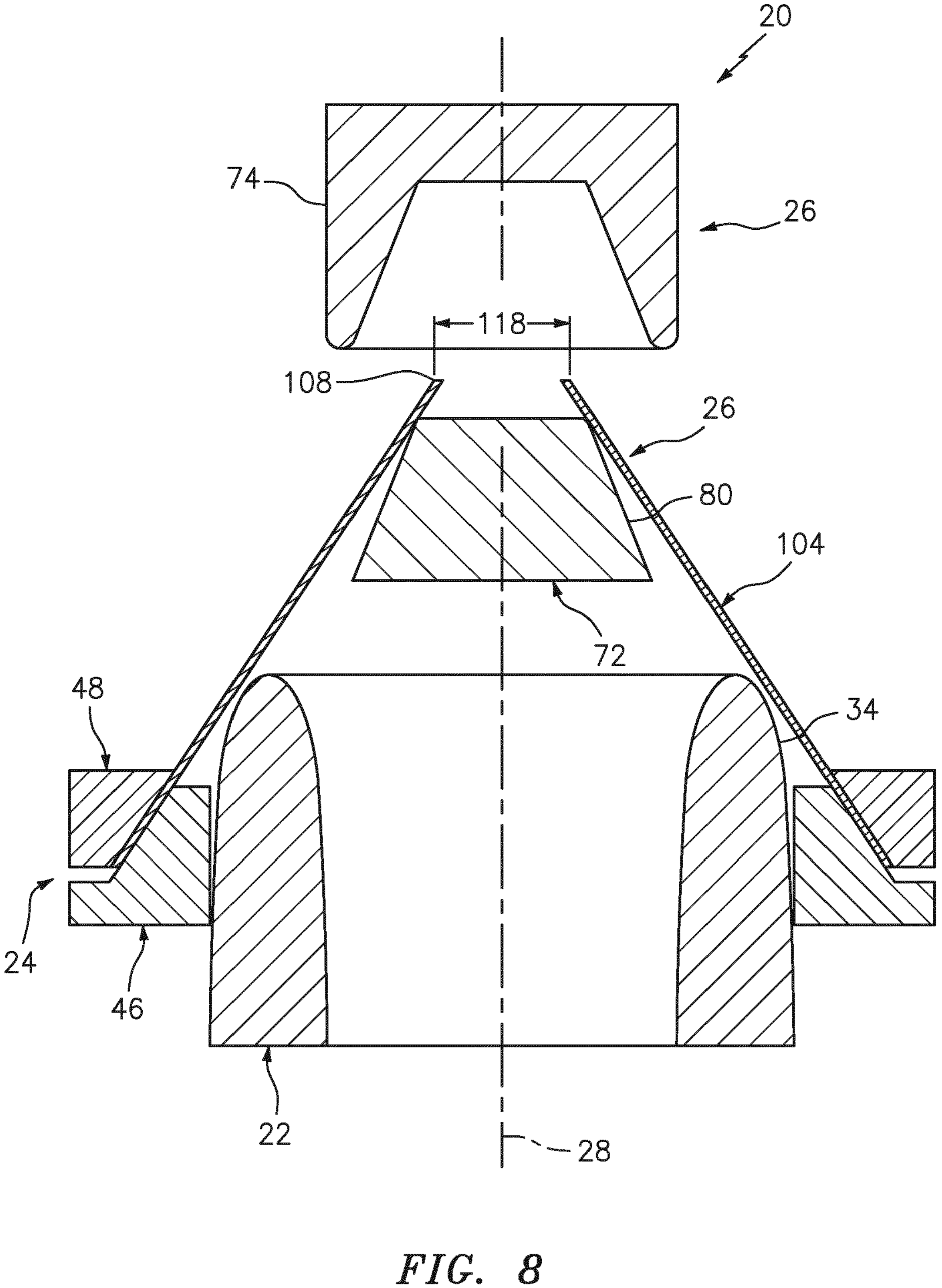

FIG. 8

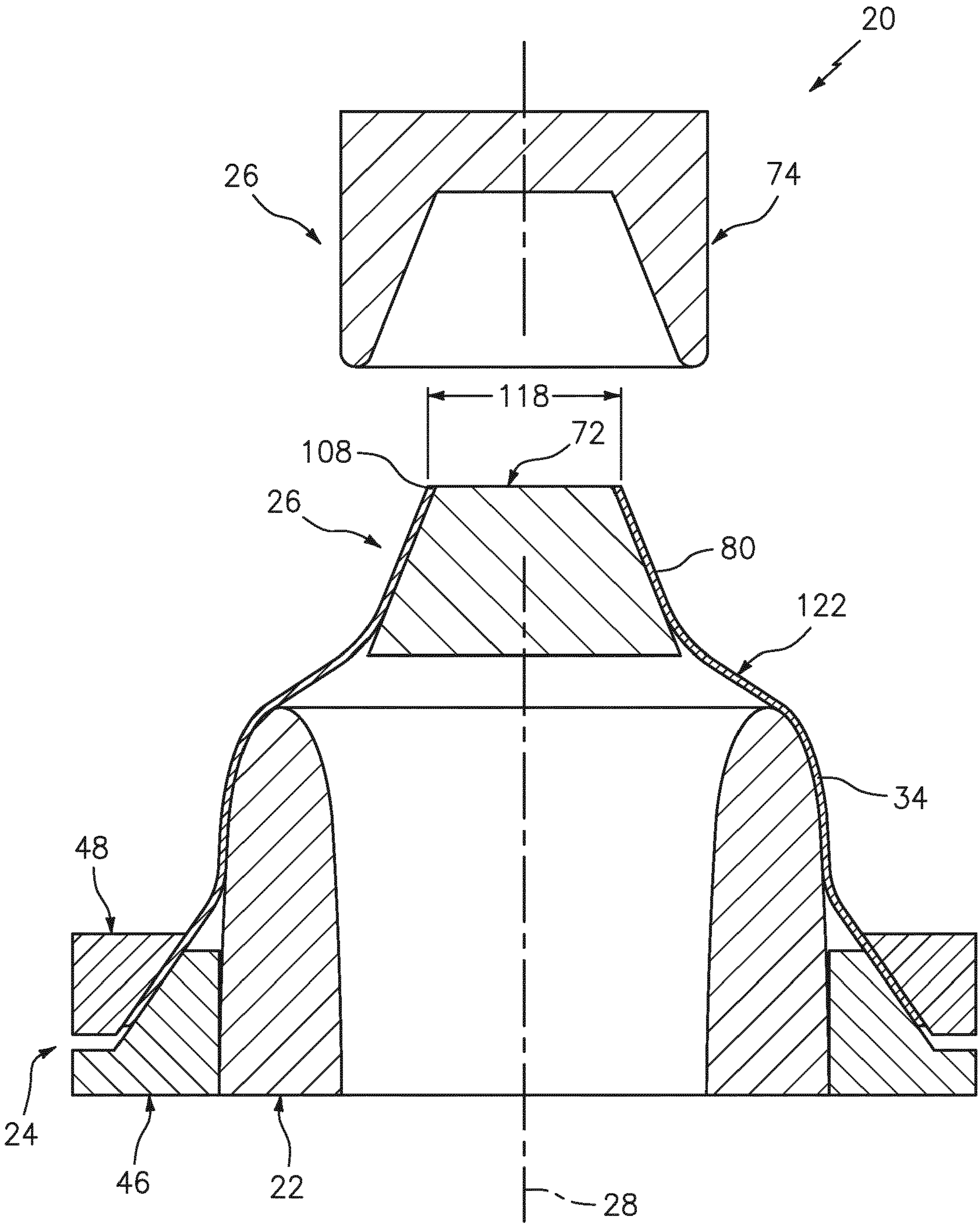

FIG. 9

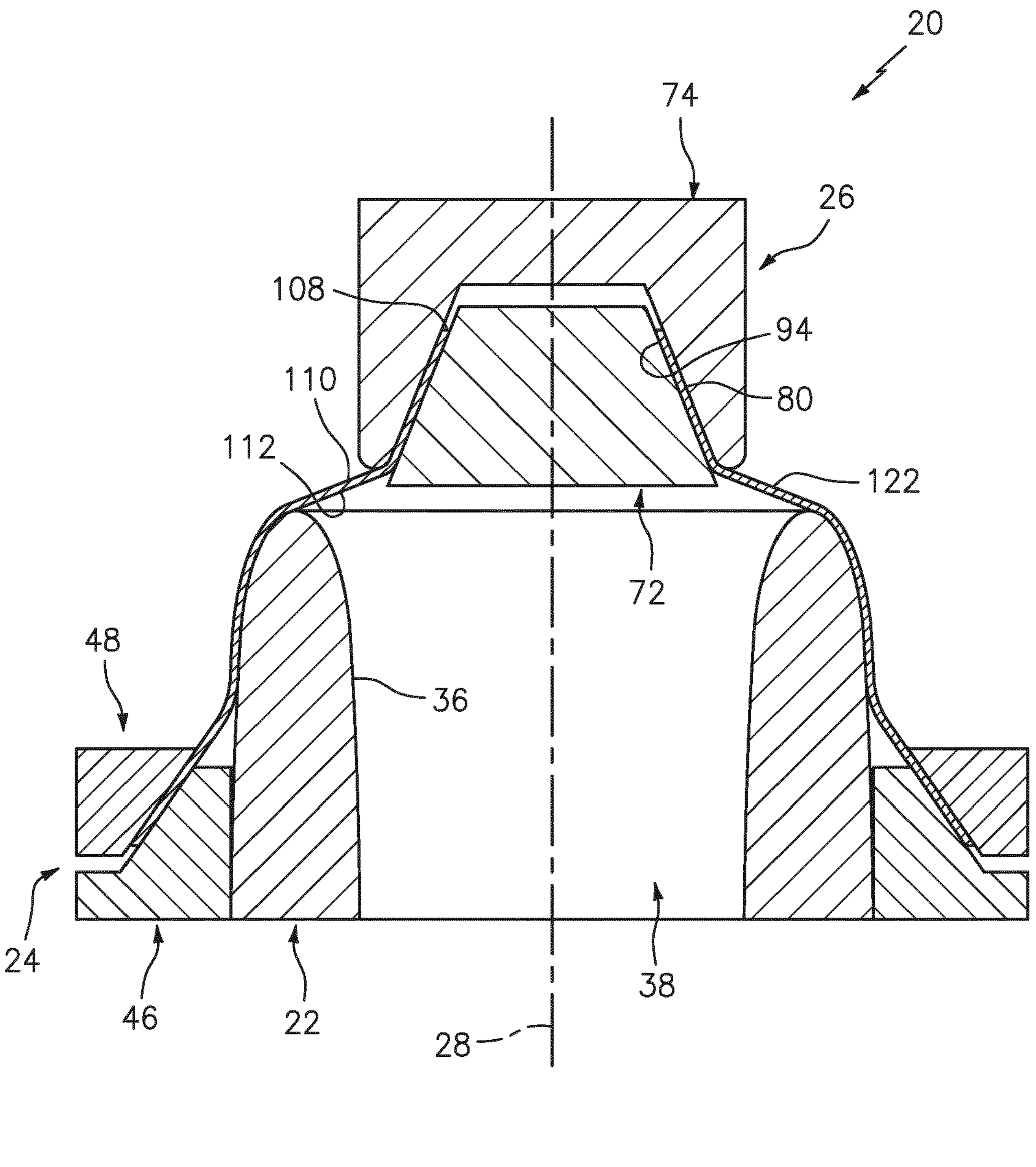

FIG. 10

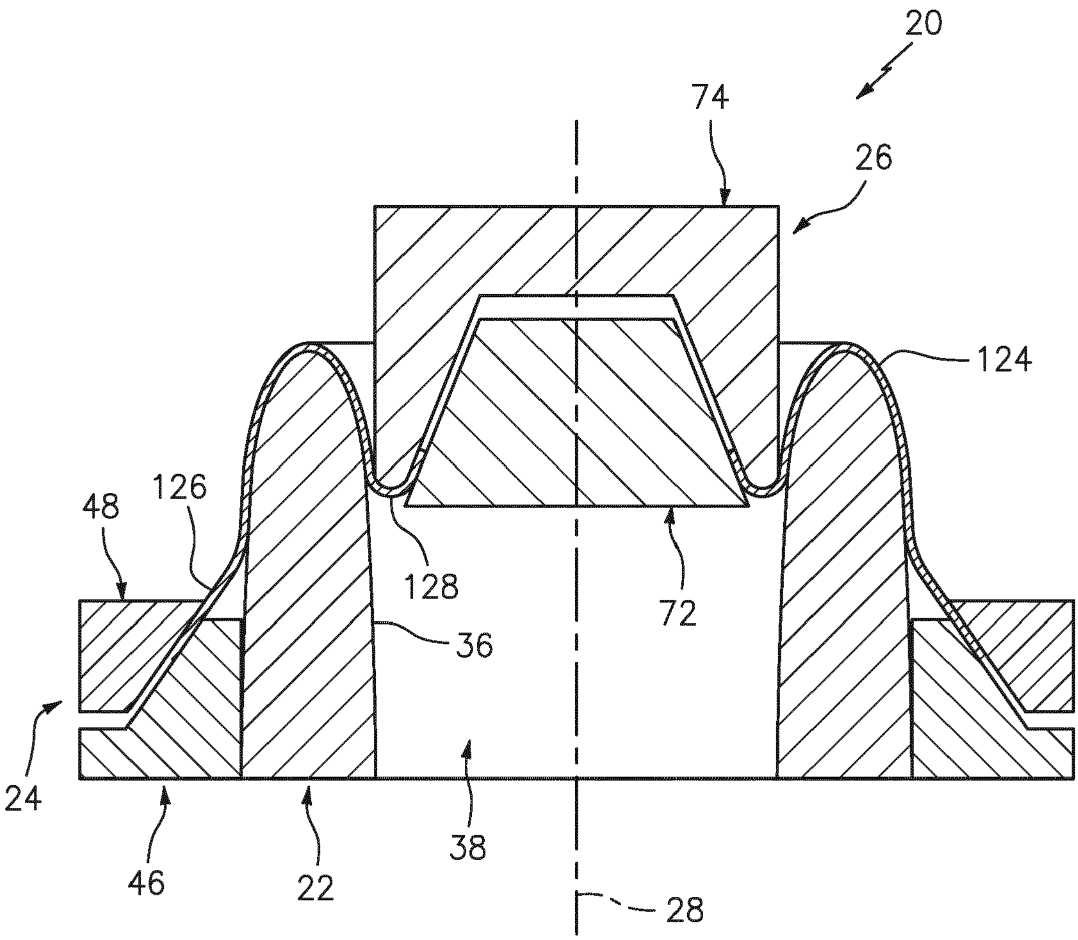

FIG. 11

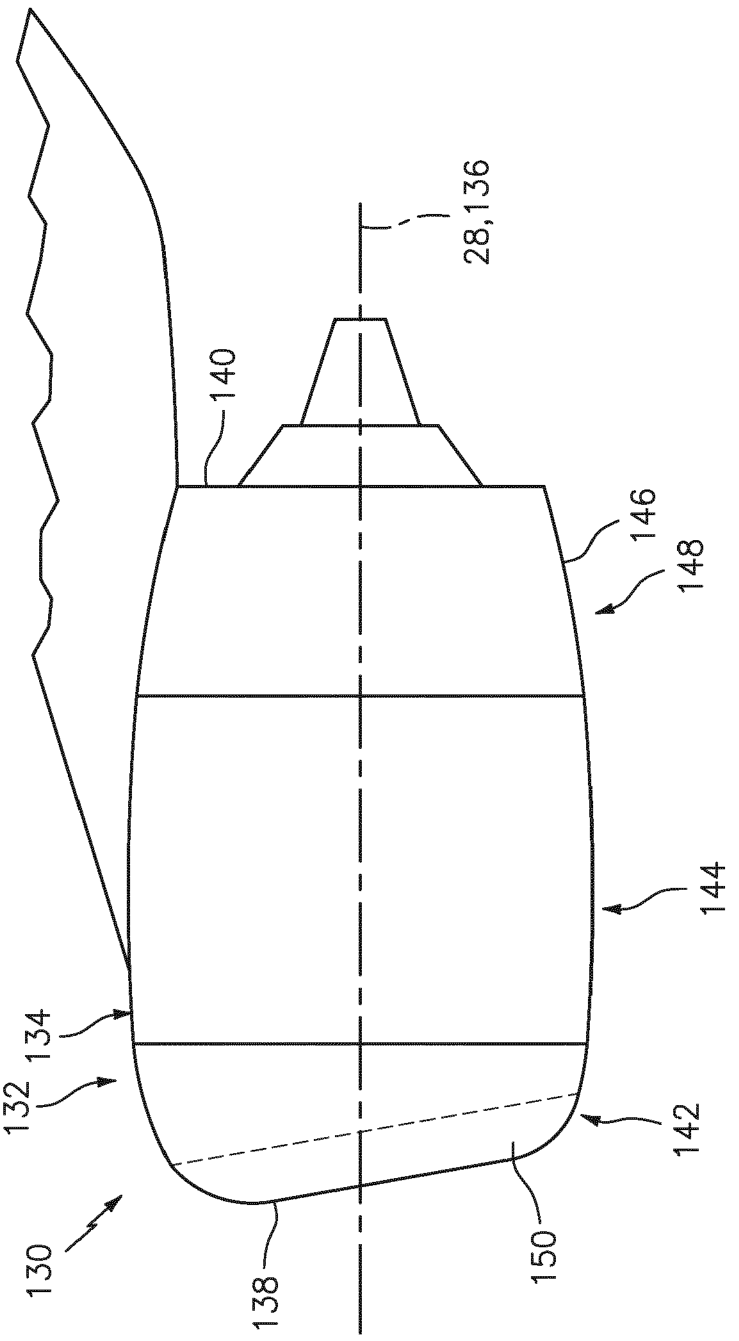

FIG. 12

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EUROPEAN SEARCH REPORT

Application Number
EP 21 15 4412

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2015/004152 A1 (LUDLOW MICHAEL [GB]) 15 January 2015 (2015-01-15) * paragraphs [0071], [0084], [0117], [0122]; claims 9, 40; figures 1-13 *	1-15	INV. B21D22/06 B21D22/24 B21D22/22 B21D53/92 B21D25/02
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B21D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	18 June 2021	Vassoille, Philippe

CATEGORY OF CITED DOCUMENTS

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18-06-2021

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