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(71) Applicant: **NOVELIS INC.** [CA/US]; One Phipps Plaza, 3550 Peachtree Rd, Suite 1100, Atlanta, Georgia 30326 (US).

(72) Inventors: **JONES, Candice**; c/o Novelis Inc., 1950 Vaughn Road, Kennesaw, Georgia 30144 (US). **NOBREGA, Carlos**; c/o Novelis Inc., 1950 Vaughn Road, Kennesaw, Georgia 30144 (US). **GUEDES, Matheus**; c/o Novelis Inc., 1950 Vaughn Road, Kennesaw, 30144 (US). **HICKEY, Stewart Edward**; c/o Novelis Inc., 1950 Vaughn Road, Kennesaw, Georgia 30144 (US).

(74) Agent: **DAVIS, Kimberlynn B.** et al.; KILPATRICK TOWNSEND & STOCKTON LLP, 1100 Peachtree Street, Suite 2800, Atlanta, Georgia 30309 (US).

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(54) Title: FORCE MEASUREMENT DURING CAN END SHELL FORMING

(57) Abstract: A tooling assembly (102) for forming a can end shell includes an upper tool assembly (104), a lower tool assembly (106), and at least one force measurement device (132) within at least one of the upper tool assembly (104) or the lower tool assembly (106). The upper tool assembly (104) and the lower tool assembly (106) cooperate to form a can end shell from a metal blank in a can end shell forming process. The force measurement device (132) measure loads in the upper tool assembly (104) and/or the lower tool assembly (106). A method of forming the can end shell includes receiving the metal blank between the upper tool assembly (104) and the lower tool assembly (106), causing the upper tool assembly (104) to cooperate with the lower tool assembly (106) such that at least one upper forming surface and at least one lower forming surface form the metal blank into the can end shell, and measuring a load using the force measurement device (132).

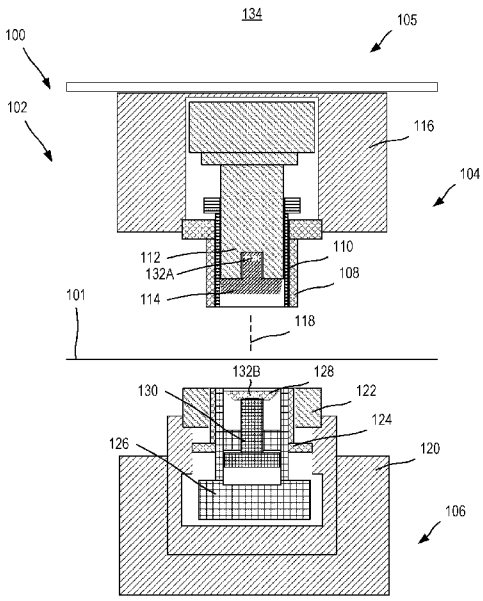

FIG. 1

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[Continued on next page]

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— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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FORCE MEASUREMENT DURING CAN END SHELL FORMING

REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 63/508,157, filed on June 14, 2023, and entitled FORCE MEASUREMENT DURING CAN END SHELL FORMING, the content of which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] This application relates to metal containers, and more particularly, to systems and methods for forming a metal can end shell that can be joined with container bodies to form the metal containers.

BACKGROUND

[0003] Metal containers, such as those intended to hold food or beverages (e.g., aluminum beverage cans), generally include a container body having an opening defined in one end, and a closure (referred to as a "container end shell" or a "can end shell") designed to close the opening of the container body. The container body and the can end shell are typically joined at their peripheries (e.g., by being crimped or rolled together) to form a liquid-tight and gas-tight joint. While some container ends are flat circular discs, container end shells are more commonly provided with raised and contoured or curled peripheral edges that facilitate the joining process.

[0004] A can end shell forming process typically includes positioning a sheet metal blank between a pair of dies which are moved to shear an edge of the blank, after which a punch descends to draw the now circular blank into a can end shell having a peripheral flange, a frustoconical wall, and an end panel. The peripheral flange of the can end shell may be curled into a downward peripheral flange suitable for double seaming operations. Subsequent processing may form a dome end panel. Such processes may be performed by a single tooling assembly or a plurality of tooling assemblies. While the traditional tooling assemblies have formed can end shells with various profiles, defective can end shells are still produced due to an inability to accurately measure the forming forces applied to the sheet metal blank. As an example, can end shells may have reduced strength due to thinning caused by excessive forces applied to the sheet metal blank, reducing the

overall strength and performance of the can end shell. Some tooling assemblies for a can end shell forming process may include a sensor behind and outside of the tooling assembly to indicate overall performance and setup, but such sensors are unable to measure or detect forming forces on the metal blank.

SUMMARY

[0005] Embodiments covered by this patent are defined by the claims below, not this summary. This summary is a high-level overview of various embodiments and introduces some of the concepts that are further described in the Detailed Description section below. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in isolation to determine the scope of the claimed subject matter. The subject matter should be understood by reference to appropriate portions of the entire specification of this patent, any or all drawings, and each claim.

[0006] According to certain embodiments, a tooling assembly for forming a can end shell includes an upper tool assembly, a lower tool assembly, and a force measurement device. The upper tool assembly and the lower tool assembly may cooperate to form a can end shell from a metal blank in a can end shell forming process. The force measurement device may be within the upper tool assembly or the lower tool assembly and may measure loads in the upper tool assembly or the lower tool assembly.

[0007] According to various embodiments, a tooling assembly for forming a can end shell includes an upper tool assembly with a die center and a lower tool assembly with a panel punch and a die core ring. In certain embodiments, the panel punch is disposed within the die core ring and opposite from the die center. The upper tool assembly and the lower tool assembly may cooperate to form a can end shell from a metal blank. The tooling assembly additionally includes at least one force measurement device within the upper tool assembly or the lower tool assembly for measuring loads in the upper tool assembly or the lower tool assembly. In certain embodiments, the at least one force measurement device is on at least one of the die center, the die core ring, or the panel punch.

[0008] According to some embodiments, a method of forming a can end shell with a tooling assembly includes receiving a metal blank between an upper tool assembly and a lower tool

assembly, where the upper tool assembly includes at least one upper forming surface and the lower tool assembly includes at least one lower forming surface. The method includes causing the upper tool assembly to cooperate with the lower tool assembly such that the at least one upper forming surface and the at least one lower forming surface form the metal blank into the can end shell. In various embodiments, the method includes measuring a load in at least one of the upper tool assembly or the lower tool assembly using at least one force measurement device within the at least one of the upper tool assembly or the lower tool assembly.

[0009] Various implementations described herein can include additional systems, methods, features, and advantages, which cannot necessarily be expressly disclosed herein but will be apparent to one of ordinary skill in the art upon examination of the following detailed description and accompanying drawings. It is intended that all such systems, methods, features, and advantages be included within the present disclosure and protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The specification makes reference to the following appended figures, in which use of like reference numerals in different figures is intended to illustrate like or analogous components.

[0011] FIG. 1 illustrates a can end shell forming system according to embodiments.

[0012] FIG. 2 illustrates a portion of a can end shell formed by the can end shell forming system of FIG. 1.

[0013] FIG. 3 illustrates another can end shell forming system according to embodiments.

[0014] FIG. 4 illustrates another can end shell forming system according to embodiments.

[0015] FIG. 5 illustrates another can end shell forming system according to embodiments.

[0016] FIG. 6 illustrates a flow chart of a method of controlling a can end shell forming according to embodiments.

DETAILED DESCRIPTION

[0017] Described herein are can end shell forming systems and associated methods with tooling assemblies having one or more force measurement devices within the tooling assemblies. Advantageously, the tooling assemblies described herein may incorporate the one or more force

measurement devices without changing the can end shell forming process itself. The one or more force measurement devices may be provided on various components of tooling assemblies for can end shell forming systems, such as but not limited to a die center, a die core ring, and/or a panel punch. In certain embodiments, the one or more force measurement devices may be provided on components of the tooling assemblies that are proximate and/or adjacent to a metal blank during a can end shell forming process using the tooling assembly. In various embodiments, the tooling assemblies include an upper tool assembly and a lower tool assembly, and either or both the upper tool assembly and the lower tool assembly may include one or more force measurement devices.

[0018] Compared to traditional can end shell forming systems, tooling assemblies with the one or more force measurement devices within the tooling assemblies allow for measurement of forming forces on metal blanks during can end shell manufacturing. In certain embodiments, the systems and methods described herein may allow for measurement of forming forces during different steps that occur in the overall can end shell forming process. Measurement of forming forces in turn may be utilized to determine characteristics of the metal blank and/or the tooling assembly itself, such as but not limited to effects of the can end shell forming process on metal properties, coating composition, lubrication, tooling design, setup, and/or arrangement, tooling wear profile, combinations thereof, and/or other characteristics as desired. The measured forming forces and/or additional information determined based on the measured forming forces may be utilized to control various aspects of the can end shell forming system and/or process, such as but not limited to type of metal utilized for the metal blank, loads applied by components of the tooling assemblies, arrangement and/or types of components of the tooling assemblies, coating compositions applied, lubrication applied, etc. In certain embodiments, the measured forming forces may provide information about formability of various types of metals during specific and/or complex forming processes that otherwise cannot be simulated using other methods and/or cannot be isolated during a can end shell forming process.

[0019] Various other benefits and advantages may be realized with the systems and methods described herein, and the aforementioned benefits and advantages should not be considered limiting.

[0020] FIG. 1 illustrates an example of a can end shell forming system 100 for forming a can end shell from a metal blank. The can end shell forming system 100 generally includes a tooling

assembly 102 supported within a press 105. The can end shell forming system 100 may include a single-station tooling assembly or a multiple station tooling assembly as desired.

[0021] As illustrated in FIG. 1, the tooling assembly 102 includes an upper tool assembly 104 with one or more upper forming surfaces and a lower tool assembly 106 with one or more lower forming surfaces. During a can end shell forming process, the upper tool assembly 104 cooperates with the lower tool assembly 106 to form a metal blank from a metal sheet 101 and to form the metal blank into a can end shell by shaping, stretching, bending, thinning, and/or otherwise forming the metal blank.

[0022] The upper tool assembly 104 of the tooling assembly 102 may include various components such as but not limited to an upper support 116 supporting a blanking die 108, an upper sleeve 110, a center support 112, and a die center 114. In various embodiments, the one or more upper forming surfaces of the upper tool assembly 104 may be various surfaces of the blanking die 108, the upper sleeve 110, and the die center 114 that contact the metal sheet 101 and/or the metal blank during the can end shell forming process. The surfaces of the blanking die 108, the upper sleeve 110, and the die center 114 forming the one or more upper forming surface may have various shapes or profiles as desired.

[0023] The upper sleeve 110 may be at least partially positioned within the blanking die 108 such that the blanking die 108 is outward from the upper sleeve 110. The die center 114 may be supported on the center support 112 and at least partially within the upper sleeve 110. The blanking die 108 may be fixed or otherwise connected to the upper support 116, and the upper sleeve 110 and the die center 114 supported on the center support 112 may be movable relative to the blanking die 108 and the upper support 116 along an axis 118. The upper sleeve 110 and the die center 114 may be movable using various mechanisms or systems as desired, and in one non-limiting example, the upper sleeve 110 and the die center 114 may be actuated via pressurized gas or fluid.

[0024] The lower tool assembly 106 of the tooling assembly 102 generally includes a lower support 120 supporting a cutting die 122, a lower sleeve 124, a die core ring 126, a panel punch 128, and a punch support 130. The surfaces of the cutting die 122, the lower sleeve 124, the die core ring 126, and the panel punch 128 may form the one or more lower forming surfaces and may have various shapes or profiles as desired.

[0025] The cutting die 122 of the lower tool assembly 106 may be fixed or otherwise connected to the lower support 120. In various embodiments, and as illustrated in FIG. 1, the lower sleeve 124 of the lower tool assembly 106 may be at least partially positioned within the cutting die 122, and the lower sleeve 124 generally may be opposite from (e.g., configured to cooperate with) the blanking die 108 of the upper tool assembly 104. The die core ring 126 may be at least partially positioned within the lower sleeve 124. In certain embodiments, the die core ring 126 may be fixed or otherwise connected to the lower support 120. In various embodiments, the panel punch 128 of the lower tool assembly 106 may be supported on the punch support 130 and at least partially within the die core ring 126.

[0026] In various embodiments, the die core ring 126 and the cutting die 122 may be fixed or otherwise connected to the lower support 120, and the lower sleeve 124 and the panel punch 128 on the punch support 130 may be movable relative to the die core ring 126 and the cutting die 122. Similar to the upper tool assembly 104, the components of the lower tool assembly 106 may be movable using various mechanisms or systems as desired, and in one non-limiting example, the lower sleeve 124 and the panel punch 128 may be actuated via pressurized gas or fluid.

[0027] In certain embodiments, and as illustrated in FIG. 1, the components of the lower tool assembly 106 may be arranged relative to the axis 118 to be opposite from (e.g., configured to cooperate with) corresponding components of the upper tool assembly 104. As non-limiting examples, the lower sleeve 124 of the lower tool assembly 106 may be provided opposite from the blanking die 108 of the upper tool assembly 104, the die core ring 126 of the lower tool assembly 106 may be provided opposite from the upper sleeve 110 of the upper tool assembly 104, and the panel punch 128 of the lower tool assembly 106 may be provided opposite from the die center 114 of the upper tool assembly 104.

[0028] During a can end shell forming process, the aforementioned components of the upper tool assembly 104 and the lower tool assembly 106 cooperate to form a can end shell 103 (see, e.g., FIG. 2) from the metal sheet 101. A non-limiting example of the can end shell forming process may include providing the metal sheet 101 between the upper tool assembly 104 and the lower tool assembly 106. The metal sheet 101 may be various metals as desired, including but not limited to aluminum, aluminum alloys, steel, or other metals as desired. In some examples, metal sheet 101 may be aluminum or an aluminum alloy in the 1xxx series, 2xxx series, 3xxx series, 4xxx

series, 5xxx series, 6xxx series, 7xxx series, 8xxx series and/or any other aluminum or aluminum alloy.

[0029] The method may include closing the press 105, thereby causing the upper tool assembly 104 to move toward the lower tool assembly 106. The method may include performing a blanking step in which forming surfaces of the cutting die 122 and forming surfaces of the blanking die 108 cooperate to cut a metal blank from the metal sheet 101. The method may include performing one or more forming steps in which the forming surfaces of the upper tool assembly 104 and the lower tool assembly 106 further form or otherwise shape the metal blank into a can end shell such as the can end shell 103 illustrated in FIG. 2.

[0030] The can end shell 103 and the particular components of the upper tool assembly 104 and/or the lower tool assembly 106 should not be considered limiting; in other embodiments, the tooling assembly 102 may include the upper tool assembly 104 and/or the lower tool assembly 106 with various components and/or components having various shapes or profiles as desired to provide a can end shell 103 having a desired profile. In certain embodiments, the components and/or characteristics of the components included with the upper tool assembly 104 and the lower tool assembly 106 may depend on a desired profile of the can end shell 103. Non-limiting examples of other tooling assemblies may include, but are not limited to, those described in U.S. Patent No. 4,516,420 to Bulso, Jr. et al., the content of which is hereby incorporated by reference in its entirety.

[0031] In various embodiments, the tooling assembly 102 includes one or more force measurement devices 132 within the upper tool assembly 104 and/or the lower tool assembly 106 for measuring loads in the upper tool assembly 104 and/or the lower tool assembly 106. The one or more force measurement devices 132 may be various suitable types of sensors or other devices suitable for measuring loads in the upper tool assembly 104 and/or the lower tool assembly 106. In various embodiments, the one or more force measurement devices 132 may measure loads during the can end shell forming process, and as discussed below, may measure forming forces on the metal during the can end shell forming process, including at various stages of the can end shell forming process.

[0032] The one or more force measurement devices 132 may be provided on various components of the upper tool assembly 104 and/or the lower tool assembly 106 as desired. As non-limiting

examples: FIG. 1 illustrates a first force measurement device 132A at a first location on the die center 114 and a second force measurement device 132B on the panel punch 128; FIG. 3 illustrates the first force measurement device 132A at a second location on the die center 114 and the second force measurement device 132B on the die core ring 126; FIG. 4 illustrates the first force measurement device 132A at the first location on the die center 114 and on the die core ring 126; and FIG. 5 illustrates the first force measurement device 132A at the second location on the die center 114 and on the panel punch 128. Other non-limiting examples of locations of the one or more force measurement devices 132 include the blanking die 108, the upper sleeve 110, the cutting die 122, and/or the lower sleeve 124. In various embodiments, the one or more force measurement devices 132 optionally are provided on a component of the upper tool assembly 104 and/or the lower tool assembly 106 with one of the forming surfaces of the tool assembly 102.

[0033] Any number of force measurement devices 132 may be utilized the upper tool assembly 104 and/or the lower tool assembly 106 as desired. As non-limiting examples, the tooling assembly 102 may include a single force measurement device 132, two force measurement devices 132 as illustrated in FIGS. 3-5, or more than two force measurement devices 132. When force measurement devices 132 are provided on both the upper tool assembly 104 and the lower tool assembly 106, the number of force measurement devices 132 on the upper tool assembly 104 need not be the same as the number of force measurement devices 132 on the lower tool assembly 104.

[0034] Still referring to FIG. 1, the can end shell forming system 100 optionally includes a controller 134 (e.g., processor and/or memory) communicatively or operably coupled (e.g., via wireless communication, wired communication, etc.) to the one or more force measurement devices 132. In such embodiments, the controller 134 may receive the measured loads from the one or more force measurement devices 132, and optionally may generate an output based on the received measured loads. In some embodiments, the controller 134 may provide the measured loads from the one or more force measurement devices 132 to an operator via a user interface and/or a remote device as the generated output. In certain embodiments, the controller 134 may provide an alert or notification to the operator based on the measured loads as the generated output.

[0035] Referring to FIG. 6, in certain embodiments, the controller 134 may measure or determine forming forces on the metal during can end shell forming based on the measured loads from the one or more force measurement devices 132. As a non-limiting example, in a block 602, the

controller 134 may receive one or more first (or calibration) loads from the one or more force measurement devices 132 during a first (or calibration) process in which the tooling assembly 102 performs the can end shell forming process but without the metal sheet.

[0036] In a block 604, the controller 134 may receive one or more second loads from the one or more force measurement devices 132 during the can end shell forming process with the metal.

[0037] In a block 606, the controller 134 may determine the forming forces on the metal during the can end shell forming process based on a difference between the measured second loads and the measured first loads. Optionally, the controller 134 may determine forming forces on the metal for each stage of the can end shell forming process (e.g., for the blanking stage, one or more shaping stages, etc.).

[0038] The measured loads from the one or more force measurement devices 132 and/or the measured forming forces based on the measured loads may be utilized to determine characteristics of the metal blank and/or the tooling assembly 102. Such determinations may be performed by the controller 134, the operator, and/or as otherwise desired. As non-limiting examples, the measured loads and/or measured forming forces may be utilized to determine metal properties during can end shell forming, effects of various coating compositions on the metal during can end shell forming, effects of various lubrications during can end shell forming, effects of various tooling assembly 102 designs, setups, or arrangements during can end shell forming, combinations thereof, and/or other characteristics as desired. In some embodiments, the measured forming forces and/or additional information determined based on the measured forming forces may be utilized to control various aspects of the can end shell forming system and/or process. Such control may be performed by the controller 134, the operator, and/or as otherwise desired. Non-limiting examples of control include controlling the type of metal supplied for the metal blank, loads applied by components of the tool assemblies 104, 106, arrangement and/or types of components of the tool assemblies 104, 106, coating compositions applied to the metal sheet 101, lubrication provided, combinations thereof, and/or other controls as desired.

[0039] In other embodiments, the measured loads from the one or more force measurement devices 132 may be utilized to perform various other processes and/or controls as desired.%

[0040] A collection of exemplary embodiments is provided below, including at least some explicitly enumerated as an "Illustration" providing additional description of a variety of example

embodiments in accordance with the concepts described herein. These illustrations are not meant to be mutually exclusive, exhaustive, or restrictive; and the disclosure not limited to these example illustrations but rather encompasses all possible modifications and variations within the scope of the issued claims and their equivalents.

[0041] Illustration 1. A tooling assembly for forming a can end shell, the tooling assembly comprising: an upper tool assembly comprising at least one upper forming surface; a lower tool assembly comprising at least lower forming surface, wherein the upper tool assembly and the lower tool assembly are configured to cooperate to form a can end shell from a metal blank in a can end shell forming process; and a force measurement device within the upper tool assembly or the lower tool assembly, wherein the force measurement device is configured to measure loads in the upper tool assembly or the lower tool assembly.

[0042] Illustration 2. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein the force measurement device is a first force measurement device and within the upper tool assembly, and wherein the tooling assembly further comprises a second force measurement device within the lower tool assembly for measuring loads in the lower tool assembly.

[0043] Illustration 3. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein the upper tool assembly comprises a die center, and wherein the force measurement device is on the die center.

[0044] Illustration 4. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein upper tool assembly further comprises at least one of an upper die with a first upper forming surface or an upper sleeve with a second upper forming surface, and wherein the die center is at partially within the at least one of the upper die or the upper sleeve.

[0045] Illustration 5. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein the lower tool assembly comprises a panel punch, and wherein the force measurement device is on the panel punch.

[0046] Illustration 6. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein the lower tool assembly further comprises at least one of a

die core ring with a first lower forming surface or a lower sleeve with a second lower forming surface, and wherein the panel punch is at least partially within the at least one of the die core ring or the lower sleeve.

[0047] Illustration 7. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein the lower tool assembly comprises a die core ring, and wherein the force measurement device is on the die core ring.

[0048] Illustration 8. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein the lower tool assembly further comprises a lower sleeve and a panel punch, wherein the panel punch is at least partially within the die core ring, and wherein the die core ring is at least partially within the lower sleeve.

[0049] Illustration 9. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, further comprising a controller communicatively coupled to the force measurement device, wherein the controller is configured to measure forming forces on the metal blank by: receiving a first measured load from the force measurement device during a calibration process without the metal blank; receiving a second measured load from the force measurement device during operation of the tooling assembly with the metal blank; and determining the forming forces on the metal blank based on a difference between the first measured load and the second measured load.

[0050] Illustration 10. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein the force measurement device is on a portion of the upper tool assembly or the lower tool assembly adjacent to the metal blank during a can end shell forming process.

[0051] Illustration 11. A tooling assembly for forming a can end shell, the tooling assembly comprising: an upper tool assembly comprising a die center; a lower tool assembly comprising a panel punch and a die core ring, wherein the panel punch is disposed within the die core ring and opposite from the die center, wherein the upper tool assembly and the lower tool assembly are configured to cooperate to form a can end shell from a metal blank; and at least one force measurement device within the upper tool assembly or the lower tool assembly, wherein the at least one force measurement device is on at least one of the die center, the die core ring, or the

panel punch, wherein the force measurement device is configured to measure loads in the upper tool assembly or the lower tool assembly.

[0052] Illustration 12. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein the at least one force measurement device is on the die center.

[0053] Illustration 13. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein the at least one force measurement device is on the die core ring.

[0054] Illustration 14. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein the at least one force measurement device is on the panel punch.

[0055] Illustration 15. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, wherein the at least one force measurement device comprises a first force measurement device and a second force measurement device, wherein the first force measurement device is on the die center, and wherein the second force measurement device is on at least one of the die core ring or the panel punch.

[0056] Illustration 16. The tooling assembly of any preceding or subsequent illustration or combination of illustrations, further comprising a controller communicatively coupled to the at least one force measurement device, wherein the controller is configured to measure forming forces on the metal blank by: receiving a first measured load from the at least one force measurement device during a calibration process without the metal blank; receiving a second measured load from the at least one force measurement device during operation of the tooling assembly with the metal blank; and determining the forming forces on the metal blank based on a difference between the first measured load and the second measured load.

[0057] Illustration 17. A method of forming a can end shell with a tooling assembly, the method comprising: receiving a metal blank between an upper tool assembly and a lower tool assembly, wherein the upper tool assembly comprises at least one upper forming surface and the lower tool assembly comprises at least one lower forming surface; causing the upper tool assembly to cooperate with the lower tool assembly such that the at least one upper forming surface and the at least one lower forming surface form the metal blank into the can end shell; and measuring a load

in at least one of the upper tool assembly or the lower tool assembly using at least one force measurement device within the at least one of the upper tool assembly or the lower tool assembly.

[0058] Illustration 18. The method of any preceding or subsequent illustration or combination of illustrations, wherein measuring the load comprises measuring the load on at least one of a die center of the upper tool assembly, a die core ring of the lower tool assembly, or 1 panel punch of the lower tool assembly.

[0059] Illustration 19. The method of any preceding or subsequent illustration or combination of illustrations, wherein the at least one force measurement device comprises an upper force measurement device within the upper tool assembly and a lower force measurement device within the lower tool assembly, and wherein measuring the load comprises measuring the loads in both the upper tool assembly and the lower tool assembly.

[0060] Illustration 20. The method of any preceding or subsequent illustration or combination of illustrations, wherein the measured load is a processing load, further comprising determining forming forces on the metal blank by: receiving a calibration load from the force measurement device during a calibration process of the upper tool assembly and the lower tool assembly before receiving the metal blank; and determining the forming forces based on a difference between the calibration load and the processing load.

[0061] As used herein, the terms "invention," "the invention," "this invention," and "the present invention" are intended to refer broadly to all of the subject matter of this patent application and the claims below. Statements containing these terms should be understood not to limit the subject matter described herein or to limit the meaning or scope of the patent claims below.

[0062] In this description, reference is made to alloys identified by AA numbers and other related designations, such as "series" or "5xxx." For an understanding of the number designation system most commonly used in naming and identifying aluminum and its alloys, see "International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys" or "Registration Record of Aluminum Association Alloy Designations and Chemical Compositions Limits for Aluminum Alloys in the Form of Castings and Ingot," both published by The Aluminum Association.

[0063] Throughout this disclosure, a reference numeral with a letter refers to a specific instance of an element and the reference numeral without an accompanying letter refers to the element generically or collectively. Thus, as an example (not shown in the drawings), device "12A" refers to an instance of a device class, which may be referred to collectively as devices "12" and any one of which may be referred to generically as a device "12".

[0064] As used herein, the meaning of "a," "an," and "the" includes singular and plural references unless the context clearly dictates otherwise.

[0065] The subject matter of embodiments of the present disclosure is described here with specificity to meet statutory requirements, but this description is not necessarily intended to limit the scope of the claims. The claimed subject matter may be embodied in other ways, may include different elements or steps, and may be used in conjunction with other existing or future technologies. This description should not be interpreted as implying any particular order or arrangement among or between various steps or elements except when the order of individual steps or arrangement of elements is explicitly described. Directional references such as "up," "down," "top," "bottom," "left," "right," "vertical," "horizontal," "lateral," "longitudinal," "front," and "back," among others, are intended to refer to the orientation as illustrated and described in the figure (or figures) to which the components and directions are referencing.

[0066] The terms "comprising," "having," "including," and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate embodiments of the invention, and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0067] The above-described aspects are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the present disclosure. Many variations and modifications can be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the present disclosure. All such modifications and variations are intended to be included herein within the scope of the present disclosure, and all possible claims

to individual aspects or combinations of elements or steps are intended to be supported by the present disclosure. Moreover, although specific terms are employed herein, as well as in the claims that follow, they are used only in a generic and descriptive sense, and not for the purposes of limiting the described embodiments, nor the claims that follow.

CLAIMS

That which is claimed:

1. A tooling assembly for forming a can end shell, the tooling assembly comprising:

an upper tool assembly;

a lower tool assembly, wherein the upper tool assembly and the lower tool assembly are configured to cooperate to form a can end shell from a metal blank in a can end shell forming process; and

a force measurement device within the upper tool assembly or the lower tool assembly, wherein the force measurement device is configured to measure loads in the upper tool assembly or the lower tool assembly.

2. The tooling assembly of claim 1, wherein the force measurement device is a first force measurement device and within the upper tool assembly, and wherein the tooling assembly further comprises a second force measurement device within the lower tool assembly for measuring loads in the lower tool assembly.

3. The tooling assembly of claim 1, wherein the upper tool assembly comprises a die center, and wherein the force measurement device is on the die center.

4. The tooling assembly of claim 3, wherein the upper tool assembly further comprises at least one of an upper die with a first upper forming surface or an upper sleeve with a second upper forming surface, and wherein the die center is at partially within the at least one of the upper die or the upper sleeve.

5. The tooling assembly of claim 1, wherein the lower tool assembly comprises a panel punch, and wherein the force measurement device is on the panel punch.

6. The tooling assembly of claim 5, wherein the lower tool assembly further comprises at least one of a die core ring with a first lower forming surface or a lower sleeve with a second lower

forming surface, and wherein the panel punch is at least partially within the at least one of the die core ring or the lower sleeve.

7. The tooling assembly of claim 1, wherein the lower tool assembly comprises a die core ring, and wherein the force measurement device is on the die core ring.

8. The tooling assembly of claim 7, wherein the lower tool assembly further comprises a lower sleeve and a panel punch, wherein the panel punch is at least partially within the die core ring, and wherein the die core ring is at least partially within the lower sleeve.

9. The tooling assembly of claim 1, further comprising a controller communicatively coupled to the force measurement device, wherein the controller is configured to measure forming forces on the metal blank by:

receiving a first measured load from the force measurement device during a calibration process without the metal blank;

receiving a second measured load from the force measurement device during operation of the tooling assembly with the metal blank; and

determining the forming forces on the metal blank based on a difference between the first measured load and the second measured load.

10. The tooling assembly of claim 1, wherein the force measurement device is on a portion of the upper tool assembly or the lower tool assembly adjacent to the metal blank during a can end shell forming process.

11. A tooling assembly for forming a can end shell, the tooling assembly comprising:

an upper tool assembly comprising a die center;

a lower tool assembly comprising a panel punch and a die core ring, wherein the panel punch is disposed within the die core ring and opposite from the die center, wherein the upper tool assembly and the lower tool assembly are configured to cooperate to form a can end shell from a metal blank; and

at least one force measurement device within the upper tool assembly and/or the lower tool assembly, wherein the at least one force measurement device is on at least one of the die center, the die core ring, or the panel punch, wherein the force measurement device is configured to measure loads in the upper tool assembly or the lower tool assembly.

12. The tooling assembly of claim 11, wherein the at least one force measurement device is on the die center.

13. The tooling assembly of claim 11, wherein the at least one force measurement device is on the die core ring.

14. The tooling assembly of claim 11, wherein the at least one force measurement device is on the panel punch.

15. The tooling assembly of claim 11, wherein the at least one force measurement device comprises a first force measurement device and a second force measurement device, wherein the first force measurement device is on the die center, and wherein the second force measurement device is on at least one of the die core ring or the panel punch.

16. The tooling assembly of claim 11, further comprising a controller communicatively coupled to the at least one force measurement device, wherein the controller is configured to measure forming forces on the metal blank by:

receiving a first measured load from the at least one force measurement device during a calibration process without the metal blank;

receiving a second measured load from the at least one force measurement device during operation of the tooling assembly with the metal blank; and

determining the forming forces on the metal blank based on a difference between the first measured load and the second measured load.

17. A method of forming a can end shell with a tooling assembly, the method comprising:

receiving a metal blank between an upper tool assembly and a lower tool assembly, wherein the upper tool assembly comprises at least one upper forming surface and the lower tool assembly comprises at least one lower forming surface;

causing the upper tool assembly to cooperate with the lower tool assembly such that the at least one upper forming surface and the at least one lower forming surface form the metal blank into the can end shell; and

measuring a load in at least one of the upper tool assembly or the lower tool assembly using at least one force measurement device within the at least one of the upper tool assembly or the lower tool assembly.

18. The method of claim 17, wherein measuring the load comprises measuring the load on at least one of a die center of the upper tool assembly, a die core ring of the lower tool assembly, or a panel punch of the lower tool assembly.

19. The method of claim 17, wherein the at least one force measurement device comprises an upper force measurement device within the upper tool assembly and a lower force measurement device within the lower tool assembly, and wherein measuring the load comprises measuring the loads in both the upper tool assembly and the lower tool assembly.

20. The method of claim 17, wherein the measured load is a processing load, further comprising determining forming forces on the metal blank by:

receiving a calibration load from the force measurement device during a calibration process of the upper tool assembly and the lower tool assembly before receiving the metal blank; and

determining the forming forces based on a difference between the calibration load and the processing load.

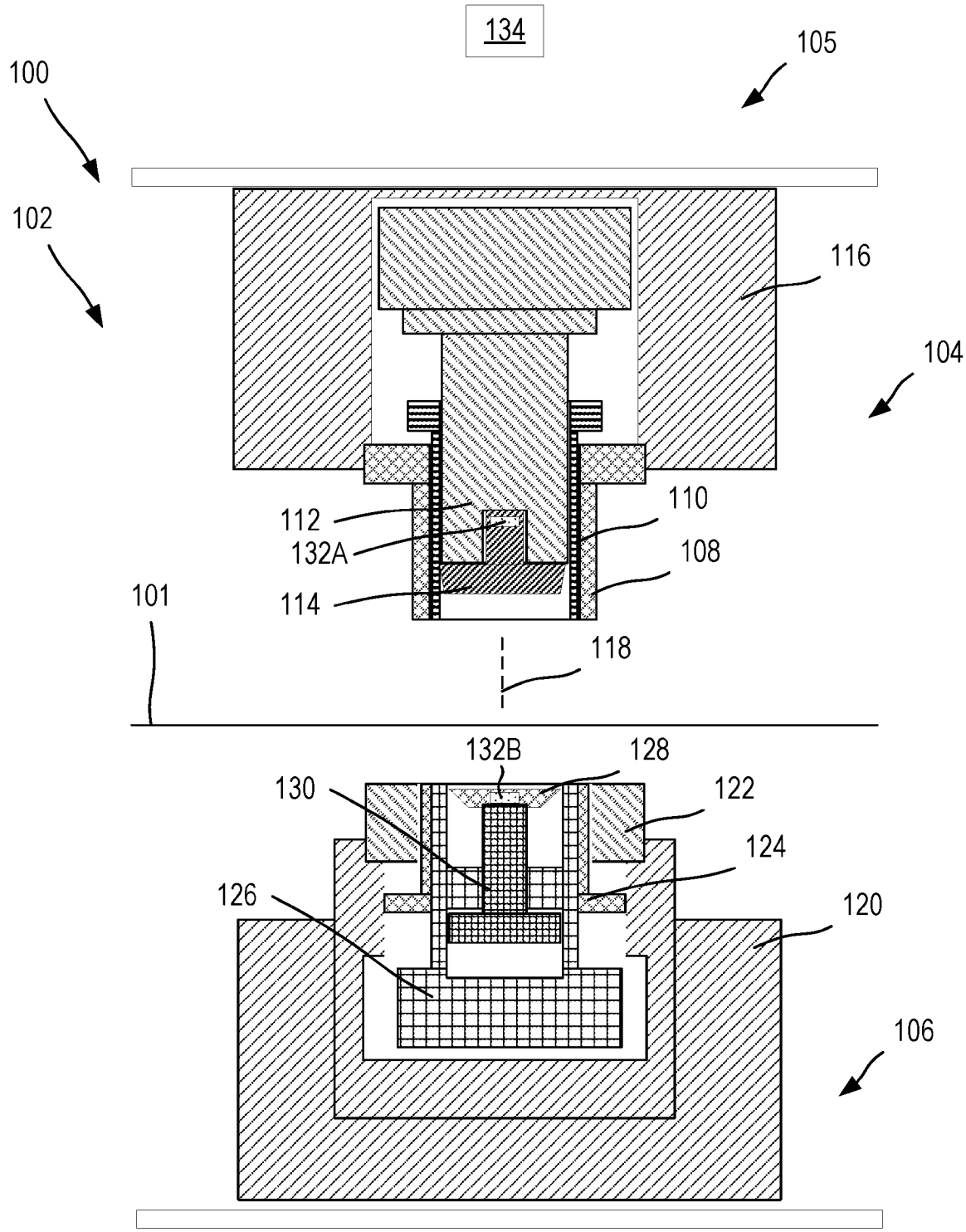
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FIG. 1

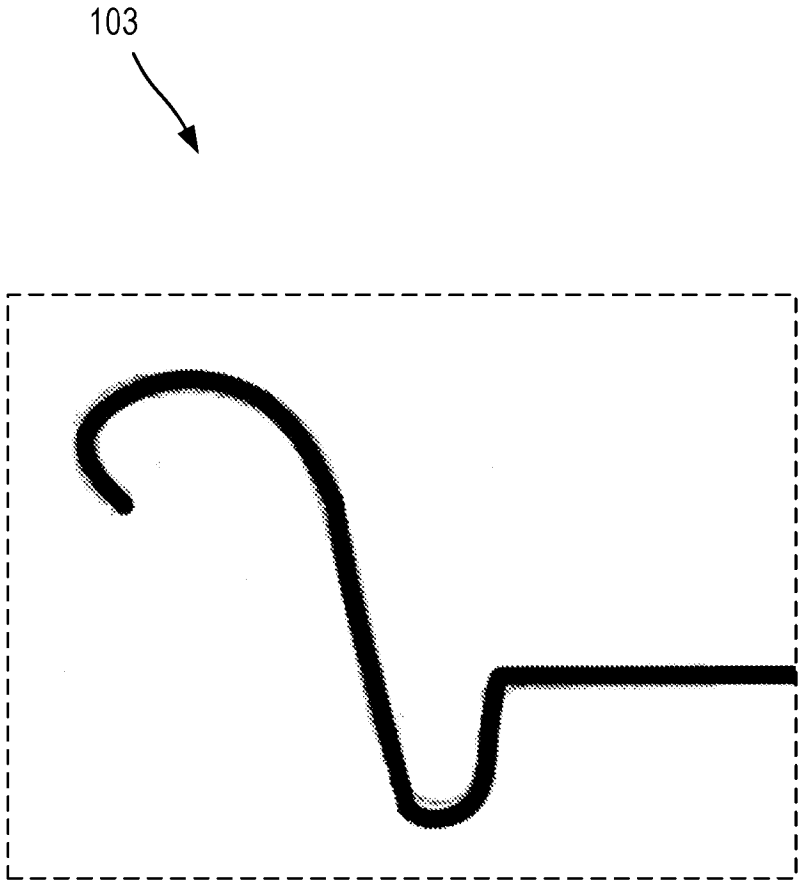

FIG. 2

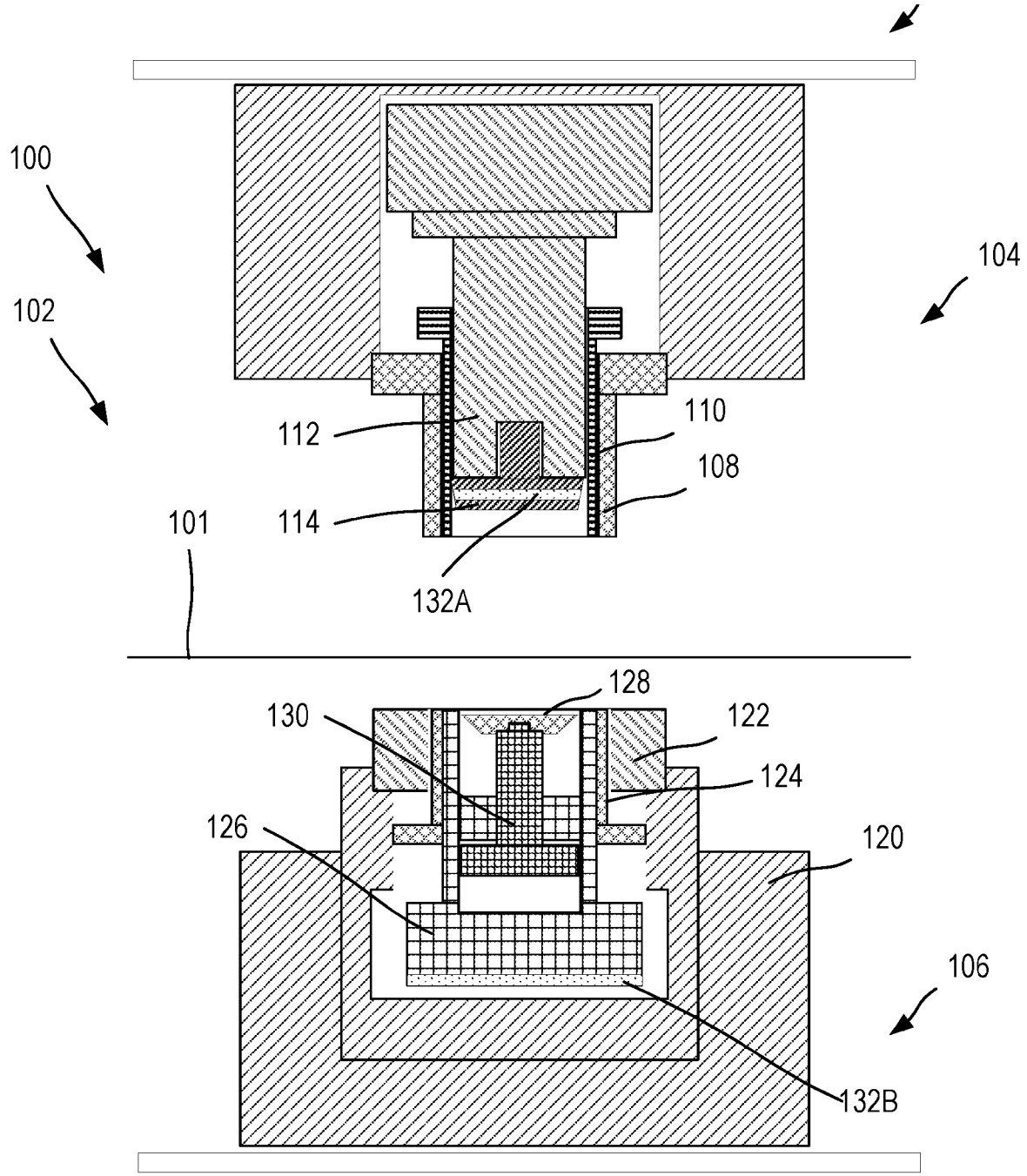
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FIG. 3

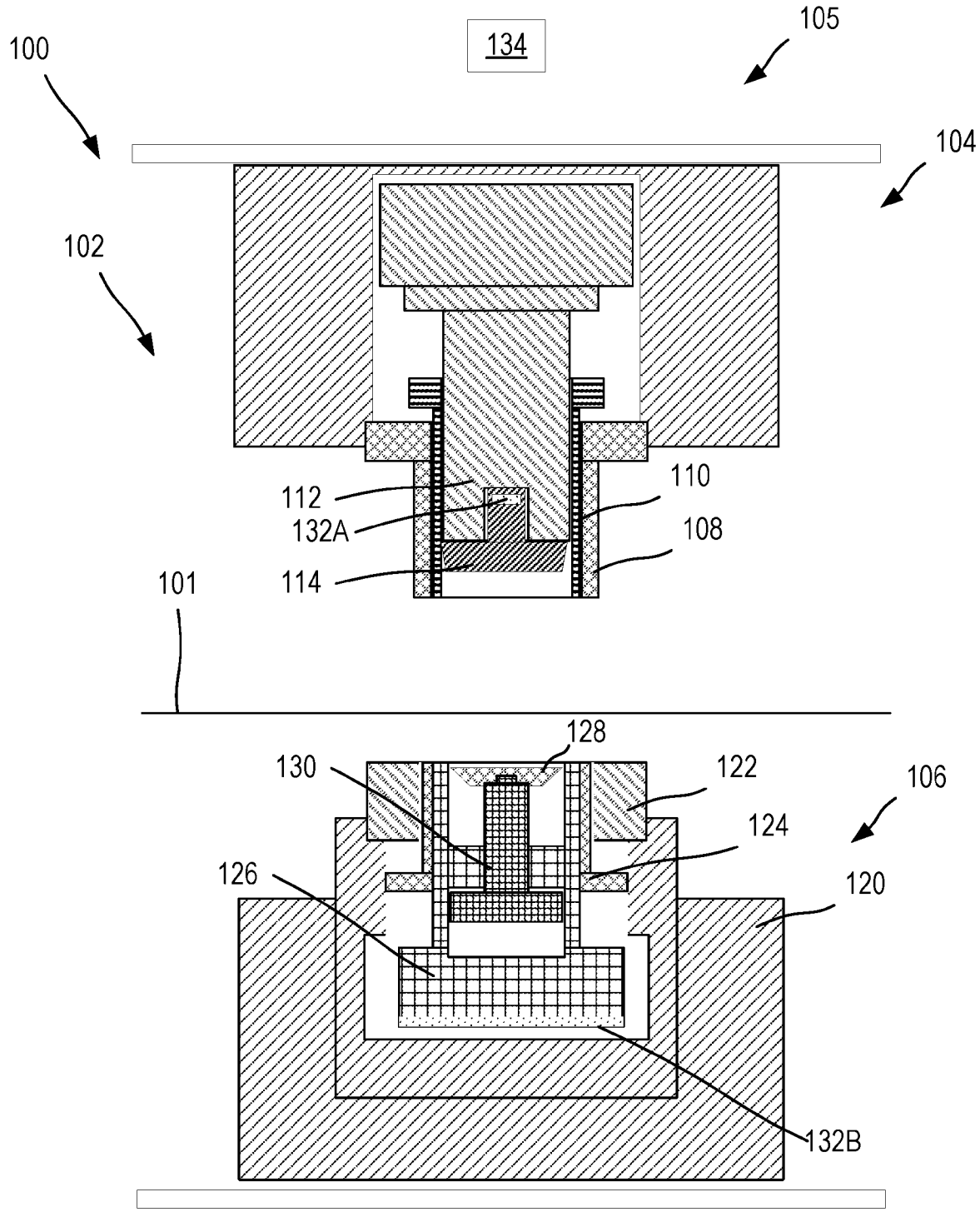
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FIG. 4

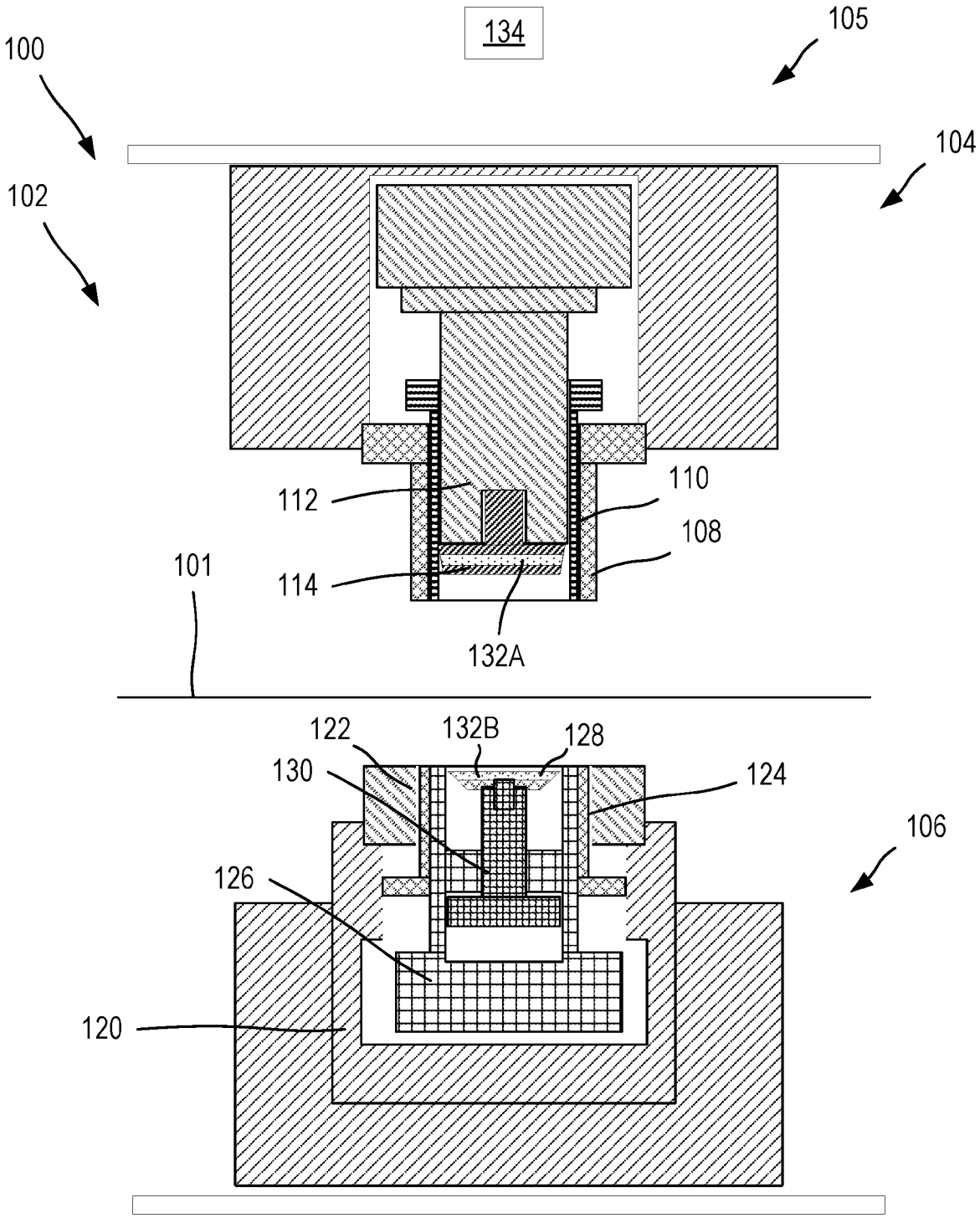
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FIG. 5

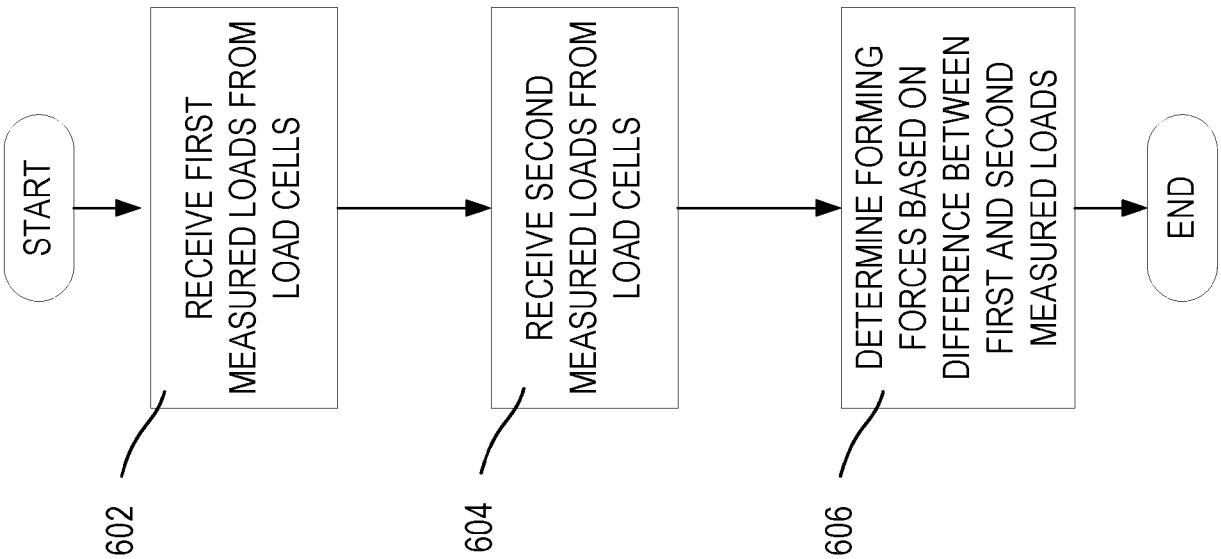
START
RECEIVE FIRST MEASURED LOADS FROM LOAD CELLS
RECEIVE SECOND MEASURED LOADS FROM LOAD CELLS
DETERMINE FORMING FORCES BASED ON DIFFERENCE BETWEEN FIRST AND SECOND MEASURED LOADS
END
602
604
606

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/033899

A. CLASSIFICATION OF SUBJECT MATTER
INV. B21D37/00 B21D51/38
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)
B21D

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	US 4 939 665 A (GOLD PHILLIP W [US] ET AL) 3 July 1990 (1990-07-03) column 5, line 28 - column 6, line 32; figures 5,5A -----	1-20
X	MAHAYOTSANUN N ET AL: "Tooling-integrated sensing systems for stamping process monitoring", INTERNATIONAL JOURNAL OF MACHINE TOOLS AND MANUFACTURE, ELSEVIER, AMSTERDAM, NL, vol. 49, no. 7-8, 6 February 2009 (2009-02-06), pages 634-644, XP026043174, ISSN: 0890-6955, DOI: 10.1016/J.IJMACHTOOLS.2009.01.009 [retrieved on 2009-02-06] page 640, paragraph 3 - page 641, line 2; figure 15 -----	1-20

☐ 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

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"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
12 September 2024	24/09/2024

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	Vesterholm, Mika

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2024/033899

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4939665 A	03-07-1990	NONE	