



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
13.12.2023 Bulletin 2023/50

(51) International Patent Classification (IPC):
B21K 23/00 (2006.01)

(21) Application number: **23177318.5**

(52) Cooperative Patent Classification (CPC):
B21K 23/00

(22) Date of filing: **05.06.2023**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

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(30) Priority: **07.06.2022 US 202217834814**

(54) **PRESS COINING SYSTEMS AND METHODS**

(57) A method for forming a stiffened panel includes compressing a metal blank (110) between a first die (102) and a second die (104). The second die comprises a plurality of discrete protrusions forming a grid structure in the negative spaces therebetween. In response to being compressed between the first and second dies, material of the metal blank is moved from between the plu-

rality of discrete protrusions and the first die to the grid structure, thereby forming the stiffened panel comprising a skin and a grid of stiffening ribs. The skin of the stiffened panel has a skin thickness which is less than an initial thickness of the metal blank. The grid of stiffening ribs has a rib height which is greater than the initial thickness of the metal blank.

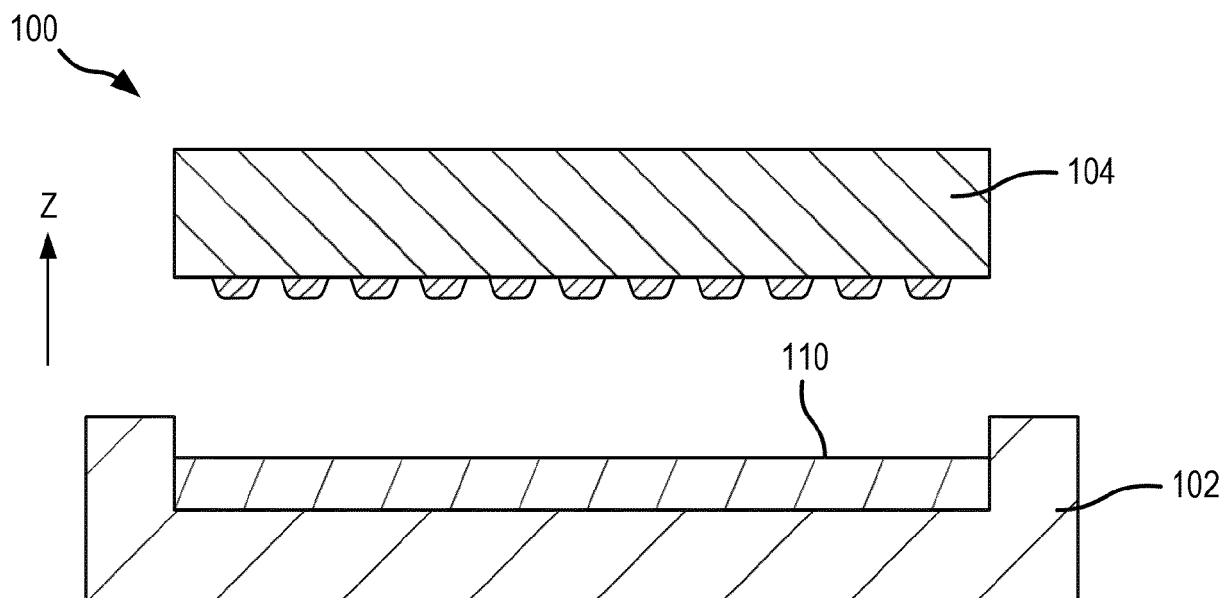


FIG. 1

Description

FIELD

[0001] The present disclosure relates generally to a process and apparatus for press coining and, more particularly, to a process and apparatus for closed-die press coining features into a metal blank.

BACKGROUND

[0002] Aeronautical and aerospace vehicles can be exposed to harsh environments. These vehicles are sometimes made with oxidation-corrosion-resistant materials well suited for service in harsh environments subjected to heat and/or pressure. Machining oxidation-corrosion-resistant materials can be difficult and time consuming due to the high material hardening rate and slow feed/speed often employed to avoid cutter wear and heat accumulation.

SUMMARY

[0003] A system for press coining a metal blank is disclosed, in accordance with various embodiments. The system comprises a first die configured to receive the metal blank, a second die configured to move toward the first die to compress the metal blank therebetween, and a plurality of discrete protrusions extending from a base surface of the second die and forming a grid structure in a negative space therebetween.

[0004] In various embodiments, the grid structure comprises at least one of an isogrid or an orthogrid.

[0005] In various embodiments, a side cross-section of each protrusion of the plurality of discrete protrusions comprises at least one of a tapered geometry or a rounded geometry.

[0006] In various embodiments, a transverse cross-section of each protrusion of the plurality of discrete protrusions comprises at least one of a quadrilateral geometry or a triangular geometry.

[0007] In various embodiments, the plurality of discrete protrusions comprises a first row of discrete protrusions, a second row of discrete protrusions spaced apart from the first row of discrete protrusions by a first distance, and a third row of discrete protrusions spaced apart from the second row of discrete protrusions by a second distance, wherein the first distance is equal to the second distance.

[0008] In various embodiments, the base surface is a planar surface.

[0009] In various embodiments, a ratio of the first distance and a width of a discrete protrusion of the plurality of discrete protrusions is between 1:10 and 1:30.

[0010] In various embodiments, the first die comprises a die recess extending into the first die from a top surface of the first die to a recess surface of the first die, and the metal blank is configured to be received at least partially

into the die recess.

[0011] In various embodiments, the top surface extends around a perimeter of the first die, the die recess extends longitudinally within the first die between opposing longitudinal sides of the recess surface, and the die recess extends laterally within the first die between opposing lateral sides of the recess surface.

[0012] A method for forming a stiffened panel is disclosed, in accordance with various embodiments. The method comprises moving a metal blank over a first die, wherein the metal blank comprises an initial thickness, moving a second die toward the second die, compressing the metal blank between the first die and the second die, wherein the second die comprises a plurality of discrete protrusions extending from a base surface of the second die and forming a grid structure in a negative space therebetween, and moving material of the metal blank from between the plurality of discrete protrusions and the first die to the grid structure, thereby forming the stiffened panel comprising a skin and a grid of stiffening ribs. The skin has a skin thickness which is less than the initial thickness. The grid of stiffening ribs has a rib height which is greater than the initial thickness.

[0013] In various embodiments, the metal blank is a planar sheet prior to being compressed between the first die and the second die.

[0014] In various embodiments, the initial thickness is between 0.05 inches and 0.50 inches.

[0015] In various embodiments, the metal blank comprises an austenitic nickel-chromium-based alloy.

[0016] In various embodiments, the method further comprises, subsequent to compressing the metal blank between the first die and the second die, removing material from the metal blank to achieve at least one of a desired rib width of the grid of stiffening ribs or a desired thickness of the skin.

[0017] In various embodiments, the method further comprises, subsequent to removing material from the metal blank, compressing the grid of stiffening ribs to flare an end of each stiffening rib of the grid of stiffening ribs.

[0018] In various embodiments, the method further comprises, heating the metal blank to a forging temperature prior to moving the metal blank over the first die.

[0019] A method for forming a stiffened panel is disclosed, in accordance with various embodiments. The method comprises press coining a metal blank with a first die and a second die to form a skin and a grid of stiffening ribs extending from the skin, removing material from the metal blank to achieve at least one of a desired rib width of the grid of stiffening ribs or a desired thickness of the skin, and compressing the grid of stiffening ribs to flare an end of each stiffening rib of the grid of stiffening ribs. Prior to the press coining, the metal blank comprises an initial thickness. After the press coining and prior to removing the material, the skin has a skin thickness which is less than the initial thickness and the grid of stiffening ribs has a rib height which is greater than the initial thick-

ness.

[0020] In various embodiments, the method further comprises heating the metal blank to a forging temperature prior to press coining the metal blank.

[0021] In various embodiments, the grid of stiffening ribs are compressed with a hydraulic press.

[0022] In various embodiments, the metal blank comprises an austenitic nickel-chromium-based alloy.

[0023] The foregoing features and elements may be combined in any combination, without exclusivity, unless expressly indicated herein otherwise. These features and elements as well as the operation of the disclosed embodiments will become more apparent in light of the following description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The subject matter of the present disclosure is particularly pointed out and distinctly claimed in the concluding portion of the specification. A more complete understanding of the present disclosure, however, may best be obtained by referring to the following detailed description and claims in connection with the following drawings. While the drawings illustrate various embodiments employing the principles described herein, the drawings do not limit the scope of the claims.

FIG. 1 is a schematic sectional illustration of an exemplary press coining tool with a metal blank installed thereon, in accordance with various embodiments;

FIG. 2 is a perspective illustration of an exemplary metal blank, in accordance with various embodiments;

FIG. 3 is a perspective illustration of an exemplary first die for the press coining tool, in accordance with various embodiments;

FIG. 4A is a perspective illustration of an exemplary second die for the press coining tool with a plurality of extrusions shaped for forming a stiffened panel having stiffening ribs formed as an orthogrid, in accordance with various embodiments;

FIG. 4B is a perspective illustration of an exemplary second die for the press coining tool with a plurality of extrusions shaped for forming a stiffened panel having stiffening ribs formed as an isogrid, in accordance with various embodiments;

FIG. 4C is a perspective illustration of an exemplary second die for the press coining tool with a plurality of extrusions shaped for forming a stiffened panel having stiffening ribs formed as an anglegrid, in accordance with various embodiments;

FIG. 5A is a perspective illustration of a portion of a stiffened panel having stiffening ribs formed as an orthogrid, in accordance with various embodiments; FIG. 5B is a perspective illustration of a portion of a stiffened panel having stiffening ribs formed as an isogrid, in accordance with various embodiments;

FIG. 5C is a perspective illustration of a portion of a stiffened panel having stiffening ribs formed as an anglegrid, in accordance with various embodiments; FIG. 6A is a schematic sectional illustration of a portion of an exemplary press coining tool in an open position, in accordance with various embodiments; FIG. 6B is a schematic sectional illustration of a portion of the exemplary press coining tool of FIG. 6A with a metal blank installed thereon, in accordance with various embodiments;

FIG. 6C is a schematic sectional illustration of a portion of the exemplary press coining tool of FIG. 6B with a metal blank installed thereon and in a closed position, in accordance with various embodiments; FIG. 7A is a schematic sectional illustration of a stiffened panel after being press coined by the press coining tool of FIG. 6A, in accordance with various embodiments;

FIG. 7B is a schematic sectional illustration of the stiffened panel of FIG. 7A during a machining process, in accordance with various embodiments;

FIG. 7C is a schematic sectional illustration of the stiffened panel of FIG. 7A during an electro chemical milling process, in accordance with various embodiments;

FIG. 8 is a schematic sectional illustration of the stiffened panel of FIG. 7B during an upsetting process, in accordance with various embodiments;

FIG. 9 is a schematic sectional illustration of the stiffened panel of FIG. 8 after undergoing the upsetting process, in accordance with various embodiments; and

FIG. 10 is a schematic illustration of an exemplary second die for the press coining tool with a plurality of extrusions shaped for forming a stiffened panel having stiffening ribs, in accordance with various embodiments.

DETAILED DESCRIPTION

[0025] The following detailed description of various embodiments herein makes reference to the accompanying drawings, which show various embodiments by way of illustration. While these various embodiments are described in sufficient detail to enable those skilled in the art to practice the disclosure, it should be understood that other embodiments may be realized and that changes may be made without departing from the scope of the disclosure. Thus, the detailed description herein is presented for purposes of illustration only and not of limitation. Furthermore, any reference to singular includes plural embodiments, and any reference to more than one component or step may include a singular embodiment or step. Also, any reference to attached, fixed, connected, or the like may include permanent, removable, temporary, partial, full or any other possible attachment option. Additionally, any reference to without contact (or similar phrases) may also include reduced contact or

minimal contact. It should also be understood that unless specifically stated otherwise, references to "a," "an" or "the" may include one or more than one and that reference to an item in the singular may also include the item in the plural. Further, all ranges may include upper and lower values and all ranges and ratio limits disclosed herein may be combined.

[0026] As used herein, the term "coining" refers to a closed-die forging process, in which pressure is applied on the surface of a metal blank in order to obtain close tolerance surfaces.

[0027] Press coining systems and methods of the present disclosure may be used for forming integral (e.g., monolithic) stiffening ribs in a metal blank or sheet. Press coining systems of the present disclosure include a first die (e.g., a bottom die) and a second die (e.g., a top die). The second die comprises a plurality of discrete protrusions sized and spaced for pushing material outside an initial profile of the metal blank to form the integral stiffening ribs. Press coining systems and methods of the present disclosure may reduce stiffened panel manufacturing time compared to traditional negative manufacturing methods (i.e., material removal processes) such as milling or grinding.

[0028] Referring to FIG. 1, a press coining system 100 (also referred to herein as a press coining tool) for press coining a metal blank is schematically illustrated, in accordance with various embodiments. Press coining system 100 includes a first die 102 (e.g., a bottom die) and a second die 104 (e.g., a top die) that together form a closed-die forging or coining tool. A metal blank 110, such as a thin metal sheet, may be received by first die 102. Second die 104 may be configured to move toward the first die 102 (e.g., via a hydraulic press or the like) to compress the metal blank 110 therebetween. The second die 104 is configured with a plurality of discrete protrusions 118 extending toward first die 102 and forming a grid structure in the negative spaces therebetween. In various embodiments, the plurality of discrete protrusions 118 are formed integrally with (e.g., monolithic) the first die 102. In response to the metal blank 110 being compressed between the first die 102 and second die 104, the grid structure is press coined into the metal blank to form the metal blank into a stiffened panel. In various embodiments, the metal blank 110 is made of a nickel superalloy such as an austenitic nickel-chromium-based alloy such as that sold under the trademark Inconel® which is available from Special Metals Corporation of New Hartford, New York, USA. A metal blank of the present disclosure may comprise a high strength austenitic nickel-chromium-based alloy, such as Inconel® 718. In this regard, the metal blank of the present disclosure tends to be difficult and time-consuming to machine due to the high strength of the material.

[0029] Referring to FIG. 2, illustrated is an exemplary metal blank 210 for use in the press coining system, according to various embodiments of the present disclosure. In various embodiments, metal blank 210 may be

an example of the metal blank 110 described herein with respect to FIG. 1 and FIG. 6A through FIG. 6C. The metal blank 210 extends longitudinally along a longitudinal centerline of the metal blank 210 (e.g., parallel to X-axis) between and to a first end 211 of the metal blank 210 and a second end 212 of the metal blank 210. The metal blank 210 extends laterally (e.g., parallel to Y-axis) between and to a first side 213 of the metal blank 210 and a second side 214 of the metal blank 210. The metal blank 210 extends vertically (e.g., parallel to Z-axis) between and to a bottom side 215 of the metal blank 210 and a top side 216 of the metal blank 210.

[0030] Metal blank 210 may be configured as a planar sheet of material. Metal blank 210 may comprise an initial thickness 290. In various embodiments, initial thickness 290 is between 0.05 inches (0.127 cm) and 0.50 inches (1.27 cm), between 0.05 inches (0.127 cm) and 0.30 inches (1.762 cm), between 0.1 inches (0.254 cm) and 0.20 inches (0.508 cm), or between 0.14 inches (0.3556 cm) and 0.18 inches (0.4572 cm). In various embodiments, the initial thickness 290 is uniform throughout the metal blank 210.

[0031] Referring to FIG. 3, illustrated is an exemplary first die 302 for use in the press coining system, according to various embodiments of the present disclosure. In various embodiments, first die 302 may be an example of first die 102 described herein with respect to FIG. 1 and FIG. 6A through FIG. 6C. The first die 302 extends longitudinally along a longitudinal centerline of the first die 302 (e.g., parallel to X-axis) between and to a first end 311 of the first die 302 and a second end 312 of the first die 302. The first die 302 extends laterally (e.g., parallel to Y-axis) between and to a first side 313 of the first die 302 and a second side 314 of the first die 302. The first die 302 extends vertically (e.g., parallel to Z-axis) between and to a bottom side 315 of the first die 302 and a top side 316 of the first die 302.

[0032] The first die 302 is configured with at least one die recess 318; e.g., a pocket, a channel, a groove, a cavity, a depression, etc. The die recess 318 of FIG. 3 extends (e.g., partially) vertically into the first die 302 from a top surface 317 of the first die 302 to a recess surface 319 of the first die 302, where the top surface 317 of FIG. 3 is arranged around the perimeter of the first die 302 at the top side 316. The die recess 318 of FIG. 3 extends longitudinally in (e.g., within) the first die 302, for example, between opposing longitudinal sides of the recess surface 319. The die recess 318 of FIG. 3 extends laterally in (e.g., within) the first die 302, for example, between opposing lateral sides of the recess surface 319.

[0033] The recess surface 319 may be a planar surface and may have a flat geometry. The die recess 318 of FIG. 3 is configured to receive the metal blank.

[0034] Referring to FIG. 4A, illustrated is an exemplary second die 404a (referred to generally herein using reference numeral 404) for use in the press coining system, according to various embodiments of the present disclosure. In various embodiments, second die 404b may be

an example of second die 104 described herein with respect to FIG. 1 and FIG. 6A through FIG. 6C. The second die 404 extends longitudinally along a longitudinal centerline of the second die 404 (e.g., parallel to X-axis) between and to a first end 411 of the second die 404 and a second end 412 of the second die 404. The second die 404 extends laterally (e.g., parallel to Y-axis) between and to a first side 413 of the second die 404 and a second side 414 of the second die 404. The second die 404 extends vertically (e.g., parallel to Z-axis) between and to a bottom side 415 of the second die 404 and a top side 416 of the second die 404.

[0035] The second die 404 is configured with a plurality of discrete protrusions 418a (referred to generally herein using reference numeral 418) extending from a base surface 420 of the second die 404 and forming a grid structure 422a (referred to generally herein using reference numeral 422) in the negative spaces therebetween. The base surface 420 may be at the bottom side 415 of the second die 404. In various embodiments, base surface 420 is a planar surface. In various embodiments, the plurality of discrete protrusions 418 are arranged into rows 424 (extending along the X-axis) and columns 426 (extending along the Y-axis). In various embodiments, each row 424 of discrete protrusions 418 is spaced apart from an adjacent row 424 of discrete protrusions by a distance 428. In various embodiments, the distance 428 is uniform throughout the rows 424 (i.e., each row 454 is equally spaced from the adjacent rows 424). In various embodiments, the distance 428 may vary depending on the desired local stiffening. In various embodiments, each column 426 of discrete protrusions 418 is spaced apart from an adjacent column 426 of discrete protrusions by a distance 429. In various embodiments, the distance 429 is uniform throughout the columns 426 (i.e., each column 426 is equally spaced from the adjacent columns 426). In various embodiments, the distance 429 may vary depending on the desired local stiffening.

[0036] In various embodiments, each protrusion 418a comprises a square geometry. Stated differently, a transverse cross-section (i.e., in the X-Y plane) of each protrusion 418a comprises a generally square geometry or a generally rectangular geometry. In various embodiments, each protrusion 418 comprises a tapered and/or rounded geometry. Stated differently, side cross-section (i.e., in the X-Z plane and/or the Y-Z plane) of each protrusion 418 comprises a tapered geometry and/or a rounded geometry. Configuring each protrusion 418 with a tapered and/or rounded geometry may reduce strain in the metal blank during the press coining process.

[0037] In various embodiments, the grid structure 422 is an orthogrid. With combined reference to FIG. 4A and FIG. 5A, in response to being press coined, the metal blank 110 may be formed into a stiffened panel 510a comprising a skin 530a and a grid of stiffening ribs 540a. The shape of the grid of stiffening ribs 540a may be similar (e.g., substantially the same) to the shape of the grid structure 422. In this regard, stiffening ribs 540a may be

formed as an orthogrid.

[0038] Referring to FIG. 4B, illustrated is an exemplary second die 404b (referred to generally herein using reference numeral 404) for use in the press coining system, according to various embodiments of the present disclosure. In various embodiments, second die 404b may be an example of second die 104 described herein with respect to FIG. 1 and FIG. 6A through FIG. 6C.

[0039] In various embodiments, each protrusion 418b comprises a triangular geometry. Stated differently, a transverse cross-section (i.e., in the X-Y plane) of each protrusion 418b comprises a generally triangular geometry.

[0040] In various embodiments, the grid structure 422b is an isogrid. With combined reference to FIG. 4B and FIG. 5B, in response to being press coined, the metal blank 110 may be formed into a stiffened panel 510b comprising a skin 530b and a grid of stiffening ribs 540b. The shape of the grid of stiffening ribs 540b may be similar (e.g., substantially the same) to the shape of the grid structure 422b. In this regard, stiffening ribs 540b may be formed as an isogrid.

[0041] Referring to FIG. 4C, illustrated is an exemplary second die 404c (referred to generally herein using reference numeral 404) for use in the press coining system, according to various embodiments of the present disclosure. In various embodiments, second die 404c may be an example of second die 104 described herein with respect to FIG. 1 and FIG. 6A through FIG. 6C.

[0042] In various embodiments, each protrusion 418c comprises a square geometry. Stated differently, a transverse cross-section (i.e., in the X-Y plane) of each protrusion 418c comprises a generally square geometry or a generally rectangular geometry.

[0043] In various embodiments, the grid structure 422c is an anglegrid. With combined reference to FIG. 4C and FIG. 5C, in response to being press coined, the metal blank 110 may be formed into a stiffened panel 510c comprising a skin 530c and a grid of stiffening ribs 540c. The shape of the grid of stiffening ribs 540c may be similar (e.g., substantially the same) to the shape of the grid structure 422c. In this regard, stiffening ribs 540c may be formed as an isogrid.

[0044] Having described various transverse cross-section geometries with respect to FIG. 4A, FIG. 4B, and FIG. 4C herein, die protrusions of the present disclosure may comprise other geometries, such as a parallelogram or a quadrilateral, for example. In various embodiments, each protrusion 418 of a particular die comprises the same geometry. In various embodiments, each protrusion 418 of a particular die comprises a combination of two or more geometries. With momentary reference to FIG. 10, a second die 404d is illustrated having a plurality of protrusions 418d of various geometries and defining a grid structure 422d.

[0045] Referring to FIG. 6A through FIG. 6C, a press coining process is illustrated, in accordance with various embodiments. A first die 102 may be disposed with re-

spect to a second die 104. A method for forming a stiffened panel includes moving a metal blank 110 over the first die 102 (see FIG. 6B). Prior to being press coined, the metal blank comprises an initial thickness 290. Moreover, prior to moving the metal blank 110 over the first die 102, the metal blank 110 may be heated to a forging temperature. In various embodiments, the forging temperature is between 1200° F (649° C) and 2200° F (1204° C), between 1400° F (760° C) and 2000° F (1093° C), or between 1600° F (971° C) and 2200° F (1204° C). With the metal blank 110 installed over the first die 102 (e.g., disposed in the die recess 318, with momentary reference to FIG. 3), the second die 104 is moved toward the first die 102 (e.g., with a hydraulic press or the like) until the second die 104 contacts the metal blank 110. The second die 104 may continue to be moved toward the first die 102 to compress the metal blank 110. As the metal blank 110 is compressed between the first die 102 and the protrusions 118 of the second die 104, the material of the metal blank 110 located vertically (i.e., along the Z-axis) between the protrusions 118 and the first die 102 is pushed to the negative space between each of the protrusions 118 to form a skin 130 and a grid of stiffening ribs 140. Stated differently, the material of the metal blank 110 may be extruded into the negative space between each of the protrusions 118 to form the ribs 140. As the material of the metal blank 110 is extruded into the negative space between each of the protrusions 118, the material is pushed outside the initial profile of the metal blank 110.

[0046] In various embodiments, the press-coined thickness 292 of the skin 130 may be between 5% and 75% of the initial thickness 290 of the metal blank 110, between 10% and 50% of the initial thickness 290 of the metal blank 110, between 20% and 45% of the initial thickness 290 of the metal blank 110, or between 35% and 40% of the initial thickness 290 of the metal blank 110.

[0047] In various embodiments, the press-coined rib height 294 of the ribs 140 is greater than the initial thickness 290. In various embodiments, the press-coined rib height 294 of the ribs 140 is between 100% and 200% of the initial thickness 290 of the metal blank 110, between 125% and 200% of the initial thickness 290 of the metal blank 110, between 145% and 180% of the initial thickness 290 of the metal blank 110, or between 155% and 170% of the initial thickness 290 of the metal blank 110.

[0048] Referring to FIG. 7A, an exemplary stiffened panel 710 subsequent to being press coined using a press coining tool of the present disclosure is illustrated, in accordance with various embodiments. In various embodiments, stiffened panel 710 may be an example of metal blank 110 described herein with respect to FIG. 6C after being press coined into a stiffened panel. In various embodiments, the base of the ribs 740 may be rounded near the skin (e.g., at the intersection of the skin 730 and the ribs 740 due to the rounded or tapered shape

of the protrusions (e.g., protrusions 118 of FIG. 6C).

[0049] In various embodiments, the rib width 786 is directly related to the distance between adjacent protrusions (e.g., see distance 428 and/or distance 429 in FIG. 4A). In various embodiments, the ratio of rib width 786 to rib spacing 746 is between 1:5 and 1:35, between 1:10 and 1:25, or between 1:12 and 1:22. In various embodiments, the ratio of the rib height 784 to the skin thickness 782 is between 4:1 and 20:1, between 5:1 and 15:1, or between 7:1 and 13:1.

[0050] Referring to FIG. 7B, if desired, the ribs 740 and/or skin 730 may be machined to remove material therefrom to achieve a desired shape and/or size. FIG. 7B schematically illustrates a machining tool 745 (e.g., a mill, a grinding wheel, or the like) removing material from stiffened panel 710 to achieve a desired shape and/or size. FIG. 7B illustrates the machining tool 745 rotating about a centerline axis and translating along a horizontal axis (i.e., to the right in FIG. 7B as illustrated by the arrow). For example, the inner surface 732 of the skin 730 may be machined to achieve a desired final thickness 792. As a further example, the ends 742 of the ribs 740 may be machined to achieve a desired final rib height 794. As a further example, the sides 744 of the ribs 740 may be machined to achieve a desired final rib width 796.

[0051] Referring to FIG. 7C, if desired, the ribs 740 and/or skin 730 may be milled using an electro chemical milling tool 770 to remove material therefrom to achieve a desired shape and/or size. Electro chemical milling tool 770 may comprise a non-conductive coating 771. In this manner, electrical current flow and/or conductive electrolyte flow may be directed at the end 772 of the electro chemical milling tool 770. A plunge force, illustrated by arrows 773, may be applied to the electro chemical milling tool 770 during the electro chemical milling process to move the electro chemical milling tool 770 toward stiffened panel 710 to remove material therefrom. In various embodiments, the electro chemical milling tool 770 is moved only along the longitudinal axis (e.g., parallel to the direction of arrows 773 in FIG. 7C) during the electro chemical milling process.

[0052] Referring to FIG. 8 and FIG. 9, if desired, the stiffened panel 710 may undergo an upsetting process whereby the ribs 740 are compressed with a flat tool 804 (e.g., similar to second die 104 of FIG. 1 except without protrusions 118), in accordance with various embodiments. The stiffened panel 710 is placed between a first tool 802 and the second tool 804 to compress the ribs 740 to a desired rib height. By compressing the ribs 740, at least two desired outcomes may be achieved. First, the final rib height 894 of the ribs 740 is achieved in a controllable and precise manner. Second, the ends 742 of the ribs 740 are flared, thereby achieving a generally trapezoidal-shaped rib and benefiting from the structural integrity of a trapezoidal stiffener (i.e., similar to a T-shaped stiffener). In various embodiments, the upsetting process causes the ribs 740 to distort into a trapezoidal

shape with a flared end 742 that tapers toward the skin 730.

[0053] The press coining tool 100 and its components 202, 204 are described above using the terms "bottom" and "top" with reference to exemplary orientations in the drawings. The present disclosure, however, is not limited to any particular formation system orientations. For example, in other embodiments, the first die 202 may alternatively be configured as a top die and the second die 204 may alternatively be configured as a bottom die.

[0054] Benefits, other advantages, and solutions to problems have been described herein with regard to specific embodiments. Furthermore, the connecting lines shown in the various figures contained herein are intended to represent exemplary functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in a practical system. However, the benefits, advantages, solutions to problems, and any elements that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as critical, required, or essential features or elements of the disclosure. The scope of the disclosure is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." Moreover, where a phrase similar to "at least one of A, B, or C" is used in the claims, it is intended that the phrase be interpreted to mean that A alone may be present in an embodiment, B alone may be present in an embodiment, C alone may be present in an embodiment, or that any combination of the elements A, B and C may be present in a single embodiment; for example, A and B, A and C, B and C, or A and B and C. Different cross-hatching is used throughout the figures to denote different parts but not necessarily to denote the same or different materials.

[0055] Systems, methods and apparatus are provided herein. In the detailed description herein, references to "one embodiment," "an embodiment," "various embodiments," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. After reading the description, it will be apparent to one skilled in the relevant art(s) how to implement the disclosure in alternative embodiments.

[0056] Numbers, percentages, or other values stated herein are intended to include that value, and also other values that are about or approximately equal to the stated

value, as would be appreciated by one of ordinary skill in the art encompassed by various embodiments of the present disclosure. A stated value should therefore be interpreted broadly enough to encompass values that are at least close enough to the stated value to perform a desired function or achieve a desired result. The stated values include at least the variation to be expected in a suitable industrial process, and may include values that are within 10%, within 5%, within 1%, within 0.1%, or within 0.01% of a stated value. Additionally, the terms "substantially," "about" or "approximately" as used herein represent an amount close to the stated amount that still performs a desired function or achieves a desired result. For example, the term "substantially," "about" or "approximately" may refer to an amount that is within 10% of, within 5% of, within 1% of, within 0.1% of, and within 0.01% of a stated amount or value.

[0057] Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims. No claim element herein is intended to invoke 35 U.S.C. 112(f) unless the element is expressly recited using the phrase "means for." As used herein, the terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus.

[0058] Finally, it should be understood that any of the above described concepts can be used alone or in combination with any or all of the other above described concepts. Although various embodiments have been disclosed and described, one of ordinary skill in this art would recognize that certain modifications would come within the scope of this disclosure. Accordingly, the description is not intended to be exhaustive or to limit the principles described or illustrated herein to any precise form. Many modifications and variations are possible in light of the above teaching.

Claims

1. A system for press coining a metal blank, comprising:
 - a first die configured to receive the metal blank;
 - a second die configured to move toward the first die to compress the metal blank therebetween;
 - and
 - a plurality of discrete protrusions extending from a base surface of the second die and forming a grid structure in a negative space therebetween.
2. The system of claim 1, wherein the grid structure comprises at least one of an isogrid or an orthogrid.

3. The system of claim 1 or 2, wherein a side cross-section of each protrusion of the plurality of discrete protrusions comprises at least one of a tapered geometry or a rounded geometry. 5
4. The system of any preceding claim, wherein a transverse cross-section of each protrusion of the plurality of discrete protrusions comprises at least one of a quadrilateral geometry or a triangular geometry, and/or, 10
wherein the base surface is a planar surface.
5. The system of any preceding claim, wherein the plurality of discrete protrusions comprises: 15
 - a first row of discrete protrusions;
 - a second row of discrete protrusions spaced apart from the first row of discrete protrusions by a first distance; and
 - a third row of discrete protrusions spaced apart from the second row of discrete protrusions by a second distance, wherein the first distance is equal to the second distance, wherein optionally, 20
a ratio of the first distance and a width of a discrete protrusion of the plurality of discrete protrusions is between 1: 10 and 1:30. 25
6. The system of any preceding claim, wherein: 30
 - the first die comprises a die recess extending into the first die from a top surface of the first die to a recess surface of the first die; and
 - the metal blank is configured to be received at least partially into the die recess. 35
7. The system of claim 6, wherein: 40
 - the top surface extends around a perimeter of the first die;
 - the die recess extends longitudinally within the first die between opposing longitudinal sides of the recess surface; and
 - the die recess extends laterally within the first die between opposing lateral sides of the recess surface. 45
8. A method for forming a stiffened panel, the method comprising: 50
 - moving a metal blank over a first die, wherein the metal blank comprises an initial thickness;
 - moving a second die toward the second die;
 - compressing the metal blank between the first die and the second die, wherein the second die comprises a plurality of discrete protrusions extending from a base surface of the second die and forming a grid structure in a negative space 55
- therebetween; and
moving material of the metal blank from between the plurality of discrete protrusions and the first die to the grid structure, thereby forming the stiffened panel comprising a skin and a grid of stiffening ribs;
wherein the skin has a skin thickness which is less than the initial thickness; and
the grid of stiffening ribs has a rib height which is greater than the initial thickness.
9. The method of claim 8, wherein the metal blank is a planar sheet prior to being compressed between the first die and the second die.
10. The method of claim 8 or 9, wherein the initial thickness is between 0.05 inches and 0.50 inches, and/or, the method further comprising heating the metal blank to a forging temperature prior to moving the metal blank over the first die.
11. The method of any of claims 8 to 10, further comprising, subsequent to compressing the metal blank between the first die and the second die, removing material from the metal blank to achieve at least one of a desired rib width of the grid of stiffening ribs or a desired thickness of the skin.
12. The method of claim 11, further comprising, subsequent to removing material from the metal blank, compressing the grid of stiffening ribs to flare an end of each stiffening rib of the grid of stiffening ribs.
13. A method for forming a stiffened panel, the method comprising:
 - press coining a metal blank with a first die and a second die to form a skin and a grid of stiffening ribs extending from the skin;
 - removing material from the metal blank to achieve at least one of a desired rib width of the grid of stiffening ribs or a desired thickness of the skin; and
 - compressing the grid of stiffening ribs to flare an end of each stiffening rib of the grid of stiffening ribs;
 - wherein, prior to the press coining, the metal blank comprises an initial thickness; and
 - after the press coining and prior to removing the material, the skin has a skin thickness which is less than the initial thickness and the grid of stiffening ribs has a rib height which is greater than the initial thickness.
14. The method of claim 13, further comprising heating the metal blank to a forging temperature prior to press coining the metal blank, and/or, wherein the grid of stiffening ribs are compressed

with a hydraulic press.

15. The method of any of claims 8 to 12 or the method of claim 13 or 14, wherein the metal blank comprises an austenitic nickel-chromium-based alloy.

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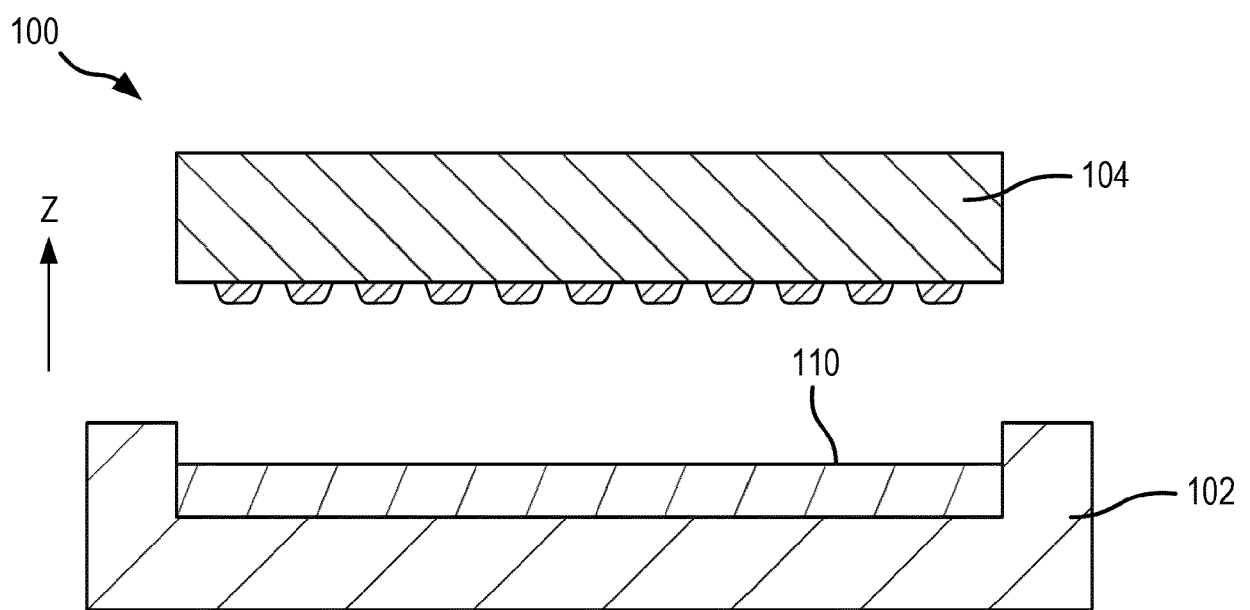


FIG. 1

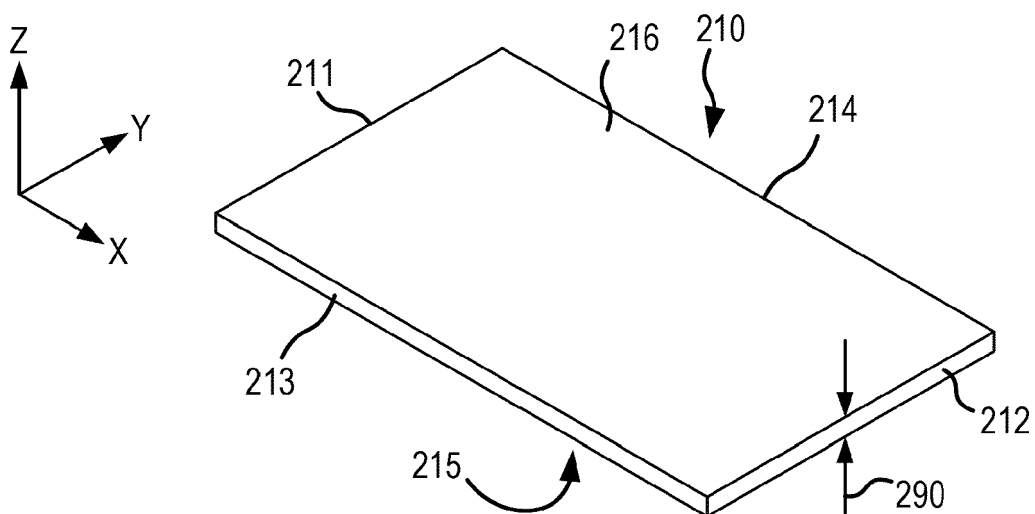


FIG. 2

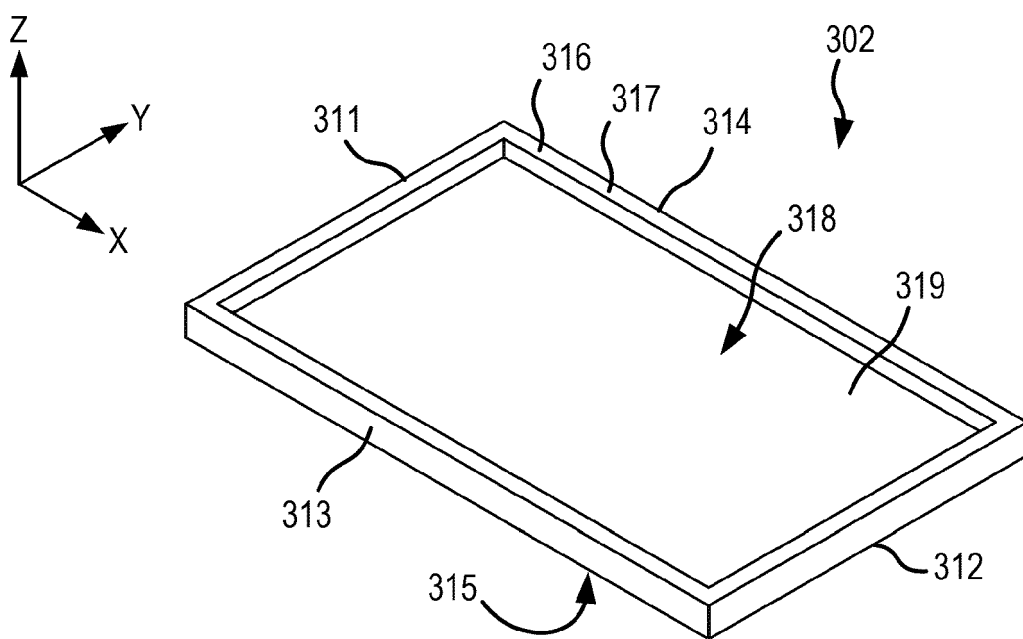


FIG. 3

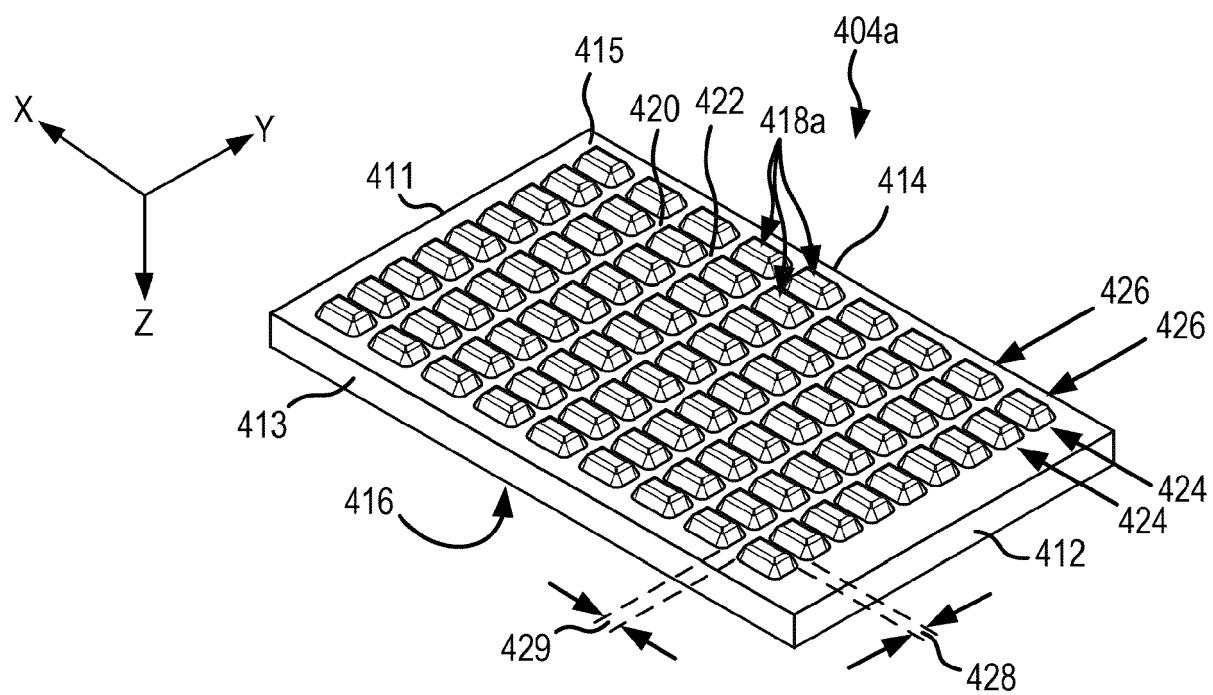


FIG. 4A

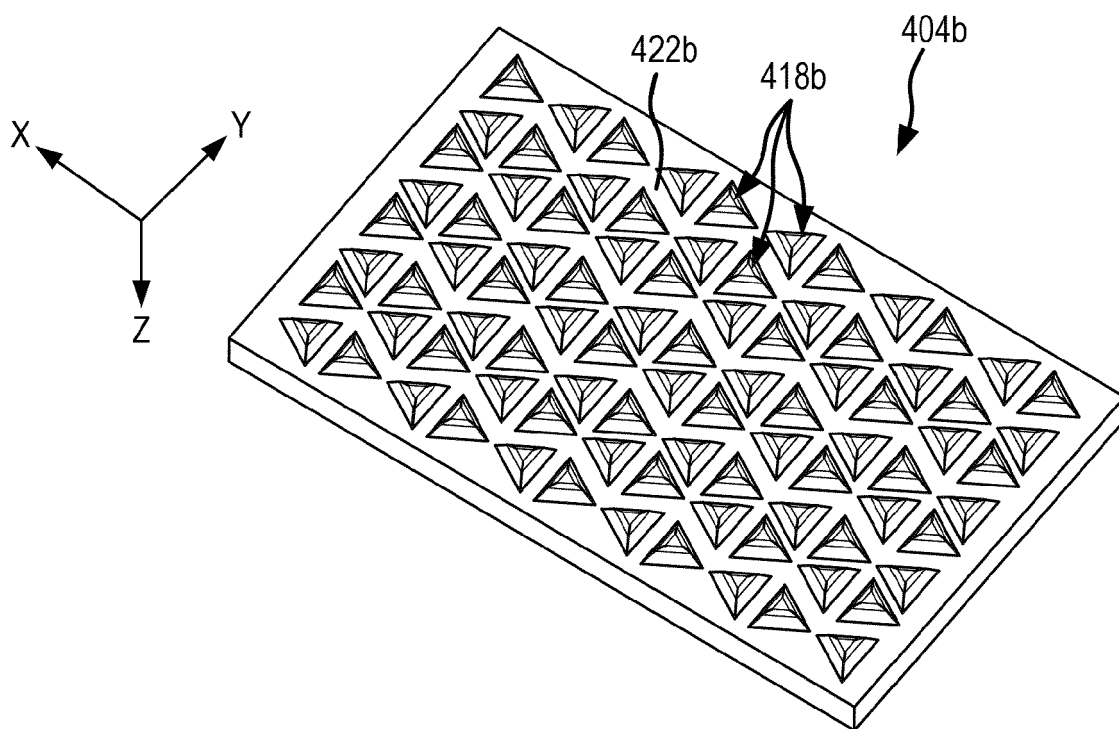


FIG. 4B

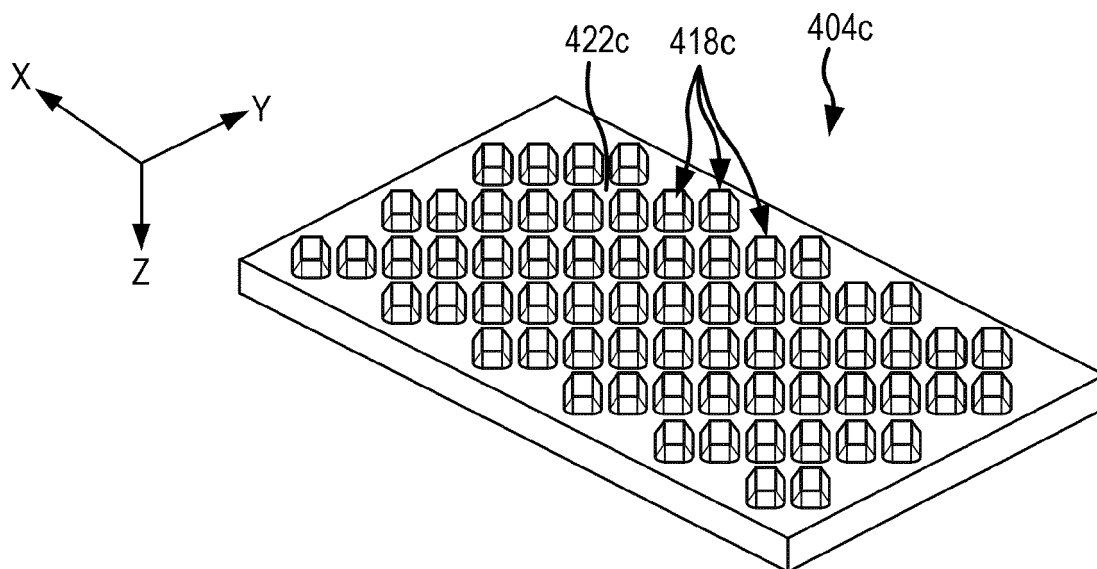


FIG. 4C

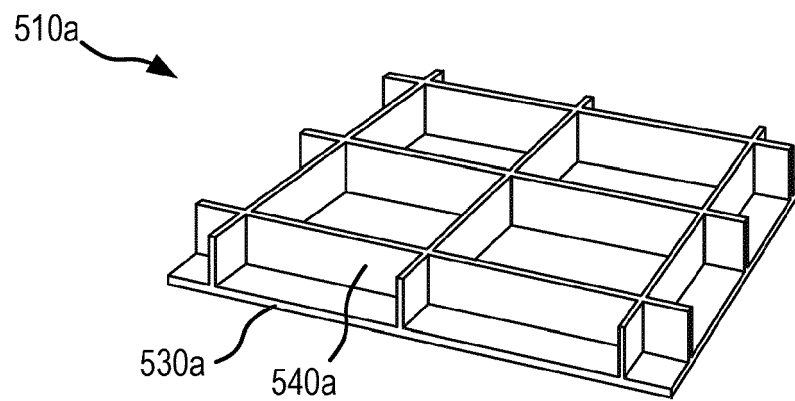


FIG. 5A

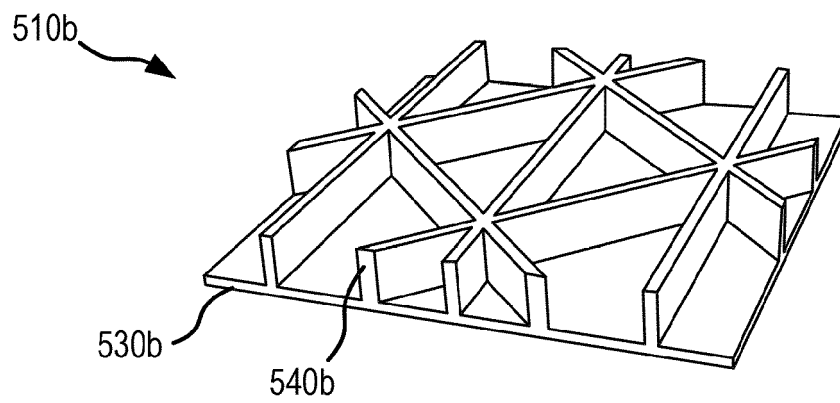


FIG. 5B

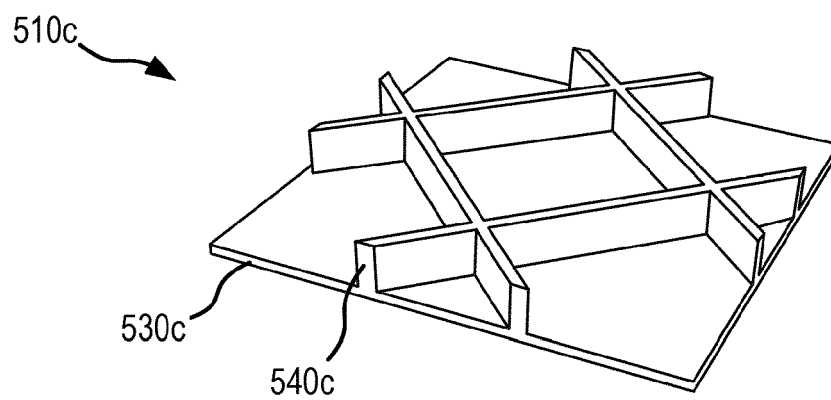


FIG. 5C

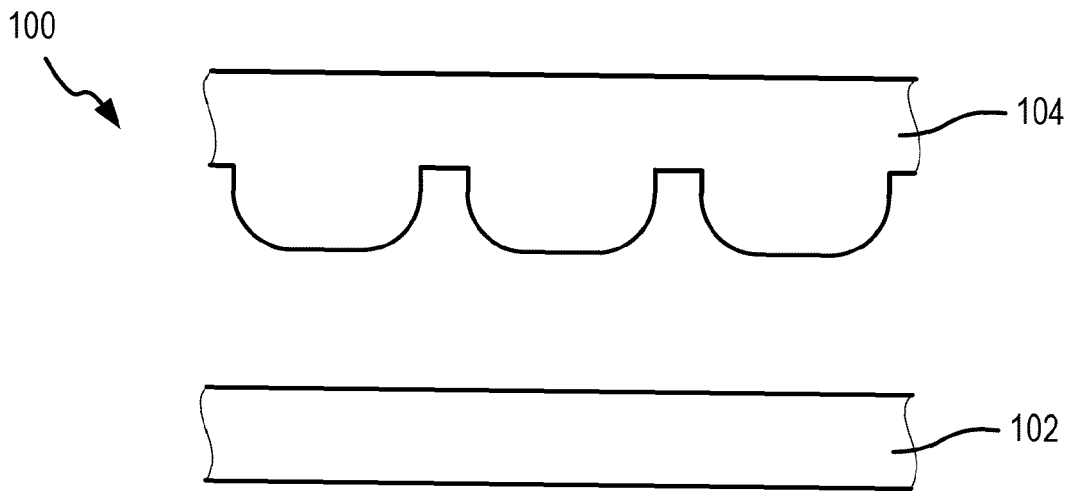


FIG. 6A

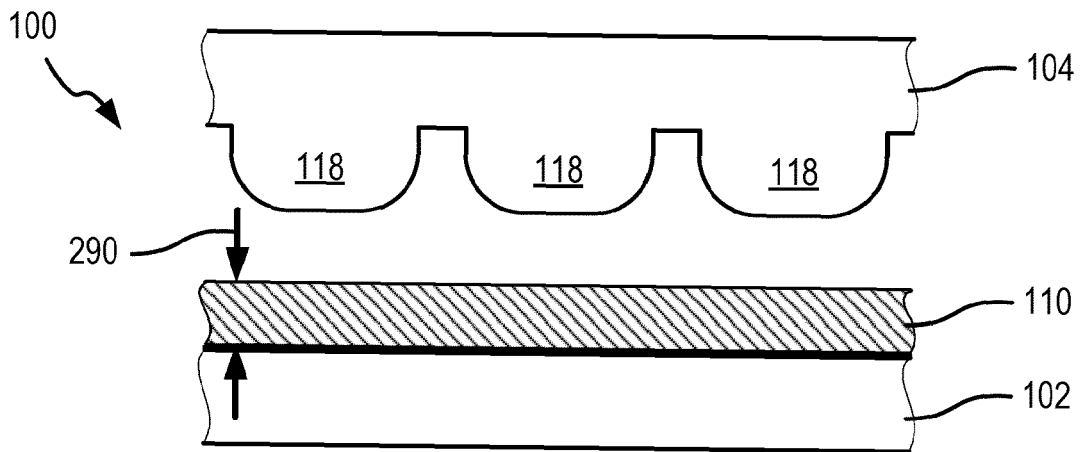


FIG. 6B

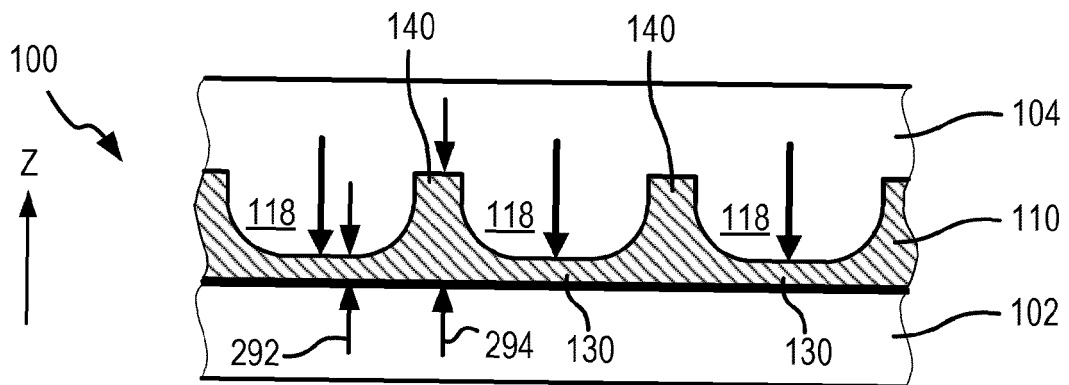


FIG. 6C

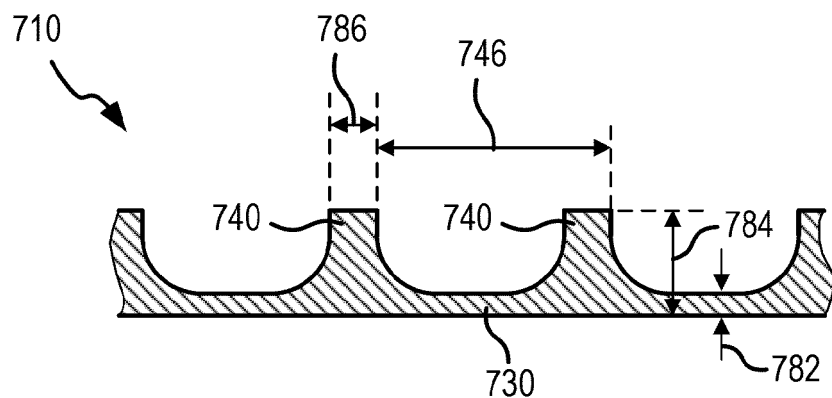


FIG. 7A

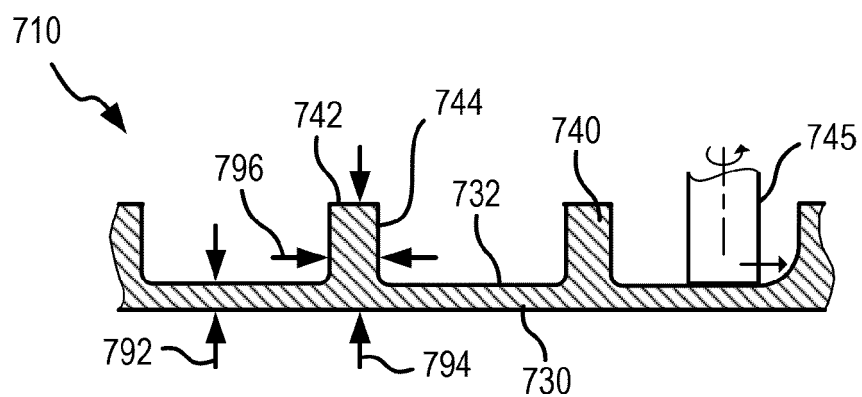


FIG. 7B

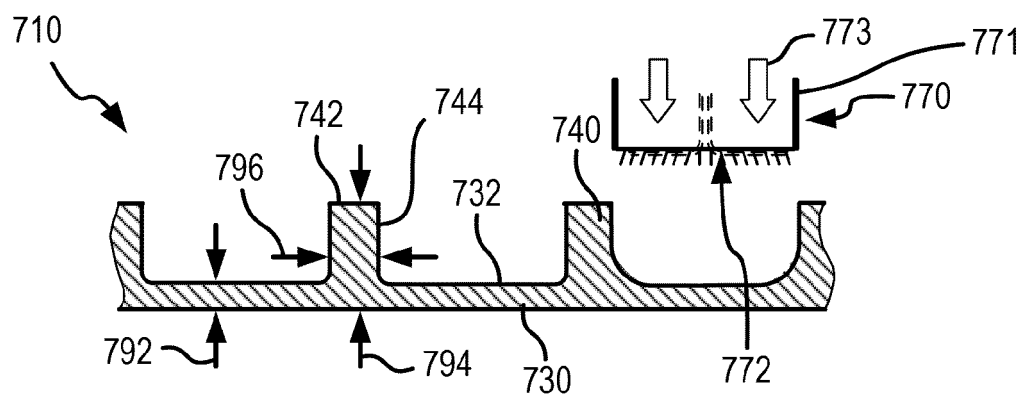


FIG. 7C

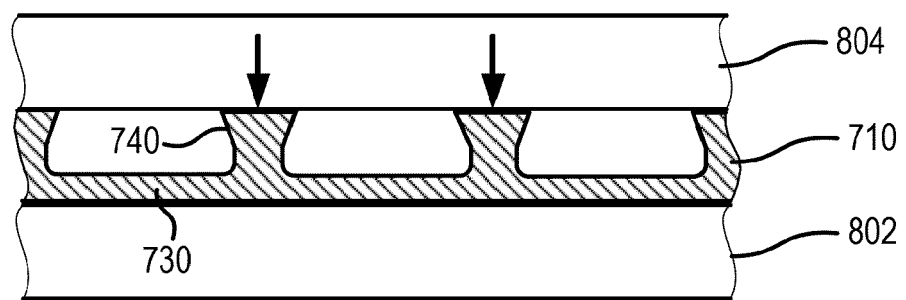


FIG. 8

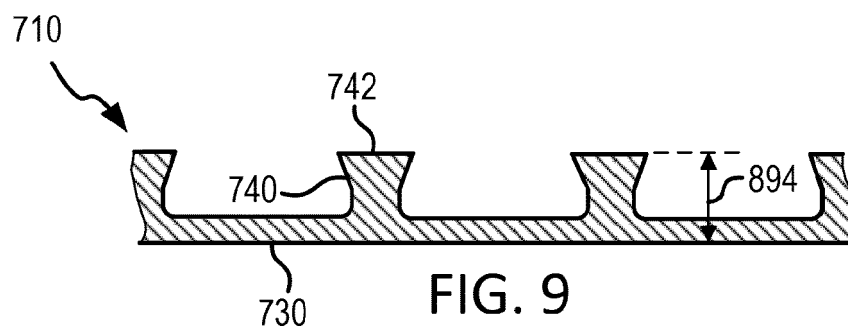


FIG. 9

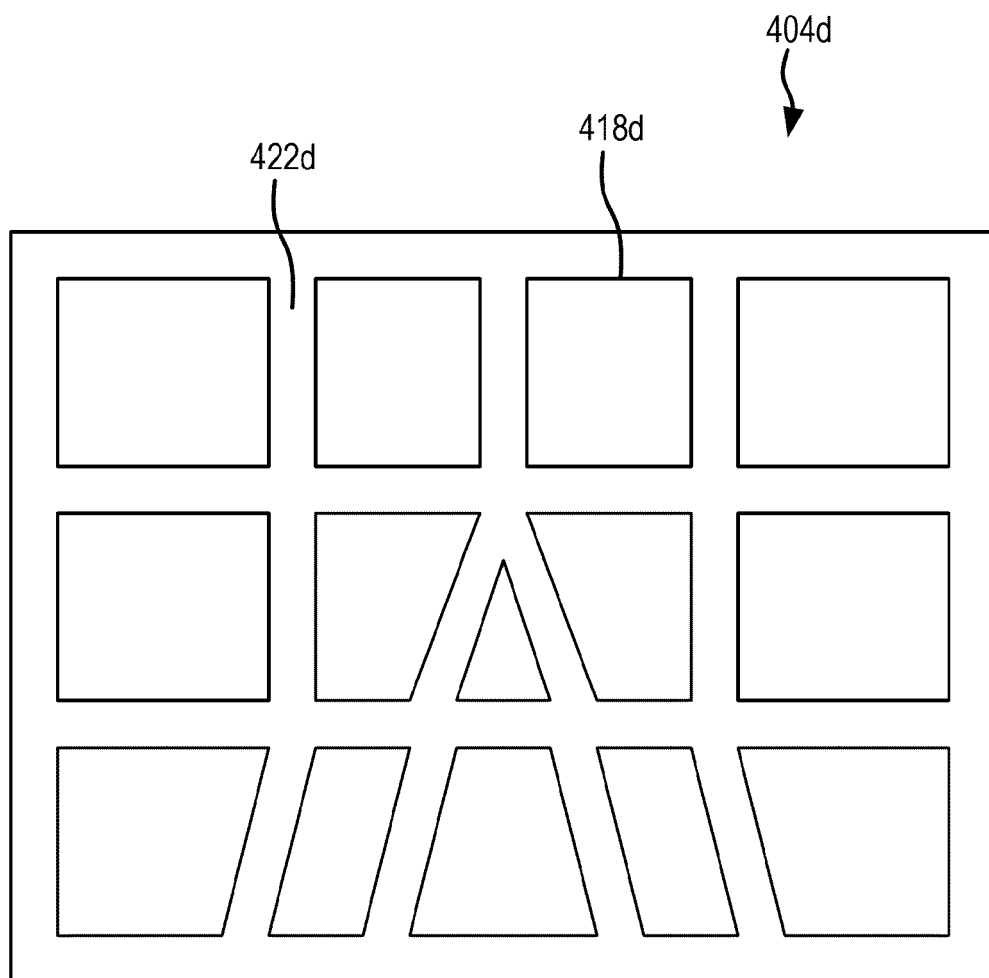


FIG. 10



EUROPEAN SEARCH REPORT

Application Number

EP 23 17 7318

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EPO FORM 1503 03.82 (P04C01)

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	FR 3 109 364 B1 (LATECOERE [FR]) 8 April 2022 (2022-04-08)	1-6, 8-11	INV. B21K23/00
Y	* claim 1; figures 4-6, 10 * -----	7, 12-15	
Y	EP 0 334 976 A1 (MELE JOSEPH J) 4 October 1989 (1989-10-04) * figures 13-17 *	7	
Y	US 8 535 783 B2 (LUTJEN PAUL M [US]; STROCK CHRISTOPHER W [US] ET AL.) 17 September 2013 (2013-09-17) * column 2, lines 38-15; figure 3 * -----	12-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			B21K B21D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 9 October 2023	Examiner Augé, Marc
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 23 17 7318

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 3109364	B1	08-04-2022	CN 115379909 A
		EP 4135917 A1	22-11-2022
		FR 3109364 A1	22-02-2023
		US 2023242276 A1	22-10-2021
		WO 2021209372 A1	03-08-2023
			21-10-2021
EP 0334976	A1	04-10-1989	NONE
US 8535783	B2	17-09-2013	EP 2395129 A1
		SG 177049 A1	14-12-2011
		US 2011300342 A1	30-01-2012
			08-12-2011