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(54) **Title:** LINEAR PASS INCREMENTAL SHEET METAL FORMING

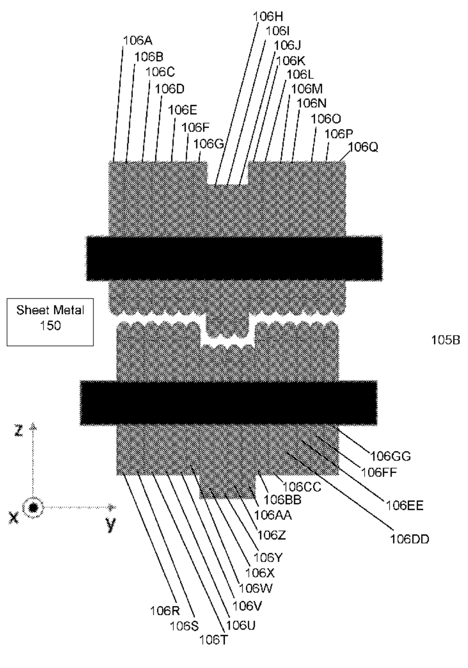

FIG. 5

105

(57) **Abstract:** In one aspect, a method for agile forming is provided (900). The method uses a minimally sized linear forming/bending system (100) that has advanced controls to be able to manufacture a wide variety of components. In another aspect a system (100) is provided for the manufacturing of metallic components by incremental bending metal. The system may use a plurality of pin stands (105) wherein one pin stand is used for shapes that have little change along one direction of the metallic component, two pin stands at some distance from one another may impose a twisting motion and may be used to control or are used to avoid twist of the metallic component, and three roll stands are used to produce curvature along the component.

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LINEAR PASS INCREMENTAL SHEET METAL FORMING

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to US Provisional Patent Application Serial No. 63/481,839, filed on January 27, 2023, and titled "LINEAR PASS INCREMENTAL SHEET METAL FORMING," the contents of which are hereby incorporated by reference in their entireties.

GOVERNMENT SUPPORT CLAUSE

[0002] This invention was made with government support under project number 2133630 awarded by the National Science Foundation. The government has certain rights in the invention.

BACKGROUND

[0003] Many structural components have what can be referred to as an extruded geometric configuration. That is the part has some shape in the x-y plane that is replicated down the z-axis. I-beams are a simple example of this. These shapes are ubiquitous for structural designs because they can have high section stiffness and the relatively complex shapes allow for useful features, such as interlocks or slides.

[0004] There are two classical methods of creating such shapes from structural materials, one is extrusion, where material is bulk formed through a die to create a shape with many degrees of freedom on the cross section. The other is roll-forming which is widely used for many architectural, automotive, appliance, furniture, and other applications. These components usually have a cross section that is of nominally constant thickness and is made by a rather continuous incremental bending process by the application of many roll passes.

[0005] Reconfigurable pin tooling uses the concepts of 3-D pin art to create a die surface based on the motion of several pins in a 2-D array. This allows the creation of dies for sheet metal forming, die-casting, injection molding and other forming or molding methods. This method has been developed in many sub-variants and has seen commercial use and has been reviewed in some depth. FIG. 1 shows some examples of reconfigurable pin tooling.

[0006] Incremental sheet forming does not use a die at all, but instead supports a sheet metal workpiece at the periphery and uses a programmed tool path to form a general 3-D sheet shape by the incremental motion of the tool. Tools may be used on one side or both to form the shape. This has seen significant commercial application in recent years.

[0007] English wheel forming is typically a manual process that uses the controlled back and forth linear motion of a sheet between two rollers to cause it to reduce in thickness and extend normal to the rolling direction to produce singly or doubly curved surfaces, such as automobile fenders. It is a well-established process that is not practiced automated commercial ways to any large extent. FIG. 2 is an illustration of the mechanics of the English wheel forming process.

[0008] Roll Forming is described briefly and schematically in FIG. 3, and is a widely used commercial technology. Part A of FIG 3. is an illustration of typical roll forming equipment. Part B is an illustration of stripped-down view of individual roll stations. Part C is an illustration of three sequences of typical “flower diagrams” where each roll operation (each operation from top to bottom) places a bend or radius in the part, to make the eventual shape.

[0009] Roll forming is a high-productivity process, in that many hundreds of pounds of materials can be processed per hour with roll-forming systems, but they rely on many machined rolls that are used in a coordinated fashion. As a result, to move from one product to another new dies must be designed, installed, and used.

SUMMARY

[0010] In one aspect, a method for agile forming is provided. The method uses a minimally sized linear forming/bending system that has advanced controls to be able to manufacture a wide variety of components. In another aspect a system is provided for the manufacturing of metallic components by incremental bending metal. The system may use a plurality of pin stands (e.g., one, two or three) wherein one pin stand is used for shapes that have little change along one direction of the metallic component, two pin stands at some distance from one another may impose a twisting motion and may be used to control or are used to avoid twist of the metallic component, and three sets of pins, along the direction of sheet travel, are used to produce curvature along the component.

[0011] In some aspects, the techniques described herein relate to a method for the manufacturing of a metallic component including: receiving a desired design for a metallic component by a forming system, wherein the forming system includes a plurality of stands, and each stand includes a plurality of pins; receiving a sheet of metal by the forming system; determining physical properties of the sheet of metal by the forming system; comparing the physical properties of the sheet of metal to the desired design by the forming system; adjusting at least some of the plurality of pins of the plurality of stands by the forming system based on the comparison; passing the sheet of metal through the plurality of pin stands to incrementally bend the sheet of metal by at least some of the plurality of pins by the forming system; determining revised physical properties of the sheet of metal by the forming system after the sheet of metal has passed through the plurality of pin stands; comparing the revised physical properties sheet of metal to the desired design by the

forming system; readjusting at least some of the plurality of pins of the plurality of stands by the forming system based on the comparison; and passing the sheet of metal through the plurality of pin stands to incrementally bend the sheet of metal by at least some of the plurality of pins by the forming system.

[0012] In some aspects, the techniques described herein relate to a method, further including repeatedly passing the sheet of metal through the plurality of pin stands and readjusting the at least some of the plurality of pins until the system determines that the physical properties of the sheet of metal match the desired design.

[0013] In some aspects, the techniques described herein relate to a method, wherein the plurality of pin stands include one, two, or three pin stands.

[0014] In some aspects, the techniques described herein relate to a method, wherein the one pin stand is used to form shapes in the metal sheet that have little change along one direction of the metal sheet.

[0015] In some aspects, the techniques described herein relate to a method, wherein the two pin stands are used to avoid twisting the metal sheet.

[0016] In some aspects, the techniques described herein relate to a method, and three pin stands are used to produce curvature along the component.

[0017] In some aspects, the techniques described herein relate to a method, wherein an orientation and an angle of each of the plurality of pin stands may be adjusted.

[0018] In some aspects, the techniques described herein relate to a method, wherein determining the physical properties of the sheet of metal by the forming system includes determining the physical properties of the sheet of metal using a camera.

[0019] In some aspects, the techniques described herein relate to a method, further including rollers or lubrication on the pins.

[0020] In some aspects, the techniques described herein relate to a system for the manufacturing of a metallic component including: one or more processors; and a computer-readable medium with computer-executable instructions stored thereon that when executed by the one or more processors cause the system to: receive a desired design for a metallic component, wherein the forming system includes a plurality of stands, and each stand includes a plurality of pins; receive a sheet of metal; determine physical properties of the sheet of metal; compare the physical properties of the sheet of metal to the desired design; adjust at least some of the plurality of pins of the plurality of stands based on the comparison; pass the sheet of metal through the plurality of pin stands to incrementally bend the sheet of metal by at least some of the plurality of pins by the forming system; determine revised physical properties of the sheet of metal after the sheet of metal has passed through the plurality of pin stands; compare the revised physical properties sheet of metal to the desired design; readjust at least some of the plurality of pins of the plurality of stands based on the comparison; and pass the sheet of metal through the plurality of pin stands to incrementally bend the sheet of metal by at least some of the plurality of pins.

[0021] In some aspects, the techniques described herein relate to a system, further including repeatedly passing the sheet of metal through the plurality of pin stands and readjusting the at least some of the plurality of pins until the system determines that the physical properties of the sheet of metal match the desired design.

[0022] In some aspects, the techniques described herein relate to a system, wherein the plurality of pin stands include one, two, or three pin stands.

[0023] In some aspects, the techniques described herein relate to a system, wherein the one pin stand is used to form shapes in the metal sheet that have little change along one direction of the metal sheet.

[0024] In some aspects, the techniques described herein relate to a system, wherein the two pin stands are used to avoid twisting the metal sheet.

[0025] In some aspects, the techniques described herein relate to a system, and three pin stands are used to produce curvature along the component.

[0026] In some aspects, the techniques described herein relate to a system, wherein an orientation and an angle of each of the plurality of pin stands may be adjusted.

[0027] In some aspects, the techniques described herein relate to a system, wherein determining the physical properties of the sheet of metal by the forming system includes determining the physical properties of the sheet of metal using a camera.

[0028] In some aspects, the techniques described herein relate to a system, further including rollers or lubrication on the pins.

[0029] In some aspects, the techniques described herein relate to a computer-readable medium with computer-executable instructions stored thereon that when executed by one or more processors cause the one or more processors to: receive a desired design for a metallic component, wherein the forming system includes a plurality of stands, and each stand includes a plurality of pins; receive a sheet of metal; determine physical properties of the sheet of metal; compare the physical properties of the sheet of metal to the desired design; adjust at least some of the plurality of pins of the plurality of stands based on the comparison; pass the sheet of metal through the plurality of pin stands to incrementally bend the sheet of metal by at least some of the plurality of pins by the forming system; determine revised physical properties of the sheet of metal after the sheet of metal has passed through the plurality of pin stands; compare the revised physical properties sheet of metal to the desired design; readjust at least some of the plurality of pins of the plurality of stands based on the comparison; and pass the sheet of metal through the plurality of pin stands to incrementally bend the sheet of metal by at least some of the plurality of pins.

[0030] In some aspects, the techniques described herein relate to a computer-readable medium, further including repeatedly passing the sheet of metal through the plurality of pin stands and readjusting the at least some of the plurality of pins until the system determines that the physical properties of the sheet of metal match the desired design.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The accompanying figures, which are incorporated herein and form part of the specification, illustrate a malware detection system and method. Together with the description, the figures further serve to explain the principles of the system and method described herein and thereby enable a person skilled in the pertinent art to make and use the system and method.

[0009] FIG. 1 is an illustration of an example reconfigurable pin tooling system;

[0010] FIG. 2 is an illustration of the mechanics of the English wheel forming process;

[0011] FIG. 3 is an illustration of example roll forming systems;

[0012] FIG. 4 is an illustration of an example forming system 100;

[0013] FIG. 5 is an illustration of an example stand 105 including pins 106;

[0014] FIG. 6A is an illustration of an example stand 105 including pins 106;

[0015] FIG. 6B is an illustration of an example stand 105 including rollers 120;

[0016] FIG. 7 is an illustration of an example stand 105 including pins 106;

[0017] FIG. 8 are illustrations of example stands 105 including pins 106;

[0018] FIG. 9 is an illustration of an example method 900 for iteratively deforming a sheet of metal; and

[0019] FIG. 10 shows an exemplary computing environment in which example embodiments and aspects may be implemented.

DETAILED DESCRIPTION

[0031] In the following description, specific details are set forth describing some embodiments consistent with the present disclosure. Numerous specific details are set forth in order to provide a thorough understanding of the embodiments. It will be apparent, however, to one skilled in the art that some embodiments may be practiced without some or all of these specific details. The specific embodiments disclosed herein are meant to be illustrative but not limiting. One skilled in the art may realize other elements that, although not specifically described here, are within the scope and the spirit of this disclosure. In addition, to avoid unnecessary repetition, one or more features shown and described in association with one embodiment may be incorporated into other embodiments unless specifically described otherwise or if the one or more features would make an embodiment non-functional. In some instances, well known methods, procedures, components, and circuits have not been described in detail so as not to unnecessarily obscure aspects of the embodiments.

[0032] FIG. 4 is an illustration of a very simple and reconfigurable forming system 100 that can be low-cost, light weight and easily placed in austere environments. The system 100 includes a controller 120 and some number of (usually 1, 2 or 3) sets of stands 105 (i.e., the stands 105A, 105B, and 105C). In some embodiments, the stands 105 are nominally aligned along a line, instead of a 2-D array. The controller 120 may be implemented by one or more general purpose computing devices such as the computing device 1000 illustrated with respect to FIG. 10

[0033] As shown by the stand 105C, each stand 105 may include a plurality of pins 106 (i.e., the pins 106A, 106B, 106C, 106D, and 106E). More or fewer pins 106 may be included in each stand 105. The extension of each pin 106 is adjustable, ideally in an automated and computer-controlled manner by the controller 120.

[0034] The sheet metal 150, which lies in the x-y plane would be pulled back and forth in the x direction. With each pass through the system 100 some or all of the pins 105 may be advanced in the z direction to begin approximating the shape of the desired component.

[0035] FIG. 5 shows a concept for one stand 105 of this system 100. Here we see a series of pins 106(i.e., the pins 106A-106GG) attached to a main support, all of which are adjustable in the z direction (and may be staggered in x to allow better adjustable engagement with the main support). The end of each pin 106 has a low friction rounded end or roller. Low friction is desired at the pin 106 ends. This can be accomplished with lubrication, rollers, and standard means such as ultrasonic vibration may also reduce friction. The sheet metal 150 lies in the x-y plane and is pulled through the pins 106 in the X direction. The pins 106 may start at the first pass where they all are placed along a line. With each pass the shapes can be developed. The focus could be on producing only one feature (such as one bend in a multi-bend configuration, such as the in the flower diagram in FIG. 3C, or the whole component could be developed at once).

[0036] A turret of rollers could also be used to allow easy change of the roller types. A piece of sheet metal 150 is introduced to the array of points when both the sheet 150 and point 106 ends are nearly linearly arrayed in the y direction. The sheet 150 will typically be much longer in the x-direction than y and is moved (usually pulled) through the pin array in the x-direction from one end to the next. The pins 106 are moved in a programmed way to cause the sheet to deform gradually and incrementally to take on the shape of the pin 106 array, which usually becomes increasingly complex with increased z displacements. The pins 106 can be advanced manually via simple methods such as screw threads, and this process may be automated by the controller 120 using stepper motors, for example.

[0037] There are multiple strategies that can be used to move from one shape to the next. Examples are shown in the Flower diagram of FIG. 3C. As the main mode of deformation is bending, rather than intended thickness reduction, and small deformation per pass is anticipated, the pulling and z-direction forces on the press stand can be relatively small and are reduced by reduced pin displacement from one pass to the next. Higher productivity is developed with larger per-pass deformation.

[0038] FIGS. 6A and 6B show how a single primary bend can be created either by pins 106 or rollers 121. FIG. 6A shows an embodiment using pins 106 (i.e., the pins 106A, 106B, and 106C). FIG. 6B shows an embodiment using rollers 121 (i.e., the rollers 121A and 121B). The sheet 150 is processed repeatedly by motion in the x-direction with an increase in the bend depth d after each pass. Dimensional measurements after each pass (allowing for relaxation by springback) can be used to program the next pass or determine when sufficient deformation is developed. Use of this repeated primary mode of deformation may be sufficient, used in a repeated way to develop many of the wide variety of components that are available by roll forming.

[0039] The system in FIGS 6A and 6B will generally produce a relatively sharp corner, depending on factors such as the strain hardening ability of the sheet 150. Radiused rollers 121 can also be used to control the radius of curvature, but a larger tool set is required. If a constant radius of curvature is desired, an incremental 4-pin system can be used such as that shown in FIG. 7. This will produce a nominally constant radius of curvature over the bent region that is set by the displacement of the pins 106 and the properties of the sheet metal 150.

[0040] Often closed, or nearly closed, sections are desired in a sheet 150 from roll forming operations. These typically require force in the y-direction in addition to the z-direction. There are numerous ways to use this approach to make sections of this type. The simplest way is to re-orient the part (e.g., sheet 150) by a 90° rotation, or a second die set could be used to do this simultaneously in two pin stands 105 that are adjacent to one another. This approach is shown in FIG. 8. The approach can be generalized to provide forces in varied directions relative to the part. This will allow the setting of corners, for example.

[0041] FIG. 8 shows a stand 105A and a stand 105B that may be adjacent to one another in a system 100. The stand 105B is offset from the stand 105A by 90°. The stand 105C is generated by combining the stands 105A and 105B.

[0042] There are several observations from roll forming that can be easily adapted here. First, for asymmetric parts, twisting is often a problem, and this is combatted by opposed twisting force between roll stands 105. This can be treated by using two pin 106 arrays with a relative twist between them to cancel out any twist developed in asymmetric forming. Also, this could be used to impart twist that is a design objective.

[0043] Programmed curvature or bends along the long direction of the part (or development of straight sections in asymmetric components) can be accomplished using three separate and sequential pin 106 array stands 105 and the relative position of these can be used to curve the component about the y or z directions. similar operations are common post roll-forming procedures with 3-roller arrays.

[0044] In all these cases, a dimensional feedback system, such as a camera, coordinate measuring or other dimensional measurements can be used to feedback the current state and this can be used to control cross section, twist, bend and so forth. Control or physical stops are often required to assure that the deformation action is along the proper line in the sheet 150. This is usually along a fixed y coordinate, but in advanced applications, this may vary systematically.

[0045] One important practical consideration is the development of systems that are sufficiently stiff and strong. Traditional engineering design of the pins 106 and supports can accomplish this, finding the optimal combination of mass and performance. Also, tongue and groove contacts between the pin segments is possible to give more lateral stiffness to the pin 106 sections.

[0046] What is described here are the relatively simple applications of this 2-D pin array with repeated sheet 150 motion. There are obvious finishing steps. All the common post-processing steps in roll forming are possible including piercing, shearing, and using rollers to emboss or develop texture. Further, it is possible to move the pins while the workpiece is in motion. This takes the current approach beyond what can be done with roll forming. This will allow for the fabrication of much more complex shapes where the cross section varies along the x direction.

[0047] This invention of forming metal 150 by repeatedly moving a sheet through a stand 105 of pins 106 that progress with each pass is lightweight, can be low-cost, will have increasing utility as control systems become more sophisticated and can process material relatively quickly with relatively little power and energy. Accordingly, it has several places where it may be of considerable use:

[0048] In space manufacturing, low earth orbit, lunar or deep space this can be used to create arbitrarily long columns from rolls of metal that are easy to store. Without gravity it becomes very simple to move the columns from end to end without support. Metal coils are efficient from a volume point of view, and this requires little energy to process and shape can be varied along the x direction for attachment points, etc.

[0049] In traditional terrestrial manufacturing, this system is well suited for rapid local manufacturing as only incoming metal is needed. This can speed development of many projects.

[0050] FIG. 9 is an illustration of a method 900 for iteratively deforming a sheet of metal. The method 900 may be implemented by the system 100, for example.

[0051] At 910, a desired design is received. The desired design may be received by the controller 120 of the system 100. The desired design may be an object or other structure that a user or administrator has selected for the system 100 to apply to a sheet of metal 150. For example, the desired design may be panel of certain dimension and thickness that the user or administrator would like to create from the sheet of metal 150. Other designs may be used.

[0052] The system 100 may include the controller 120 and a plurality of stands 105. Each stand 106 may include a plurality of pins 106 that are selectively moved (e.g., extended or retracted) to cause the sheet of metal 150 to be selectively deformed as it moves through the system 100. As will be described further below, the system 100 may repeatedly process the sheet of metal 150 using different pin 106 configurations until the sheet of metal 150 conforms to the desired design.

[0053] At 920, the sheet of metal is received. The sheet of metal 150 may be received by the system 100. The sheet of metal 150 may be a variety of metals including, but not limited to to, steel, aluminum, and titanium. Other types of metals may be used.

[0054] At 930, physical properties of the sheet of metal are determined. The properties may be determined by the controller 120 of the system 100 using a camera, for example. The properties of the sheet of metal 150 may include its overall dimensions, thickness, and any bends or curves that may be present in the sheet of metal 150. Other properties may be included. In some embodiments, determining the physical properties may include determining a shape of the sheet of metal.

[0055] At 940, the determined physical properties are compared to the desired design. The determined physical properties may be compared to the desired design by the controller 120. The controller 120 may then, based on the comparison, determine what changes to make to the sheet of metal 150 to better conform to the desired design.

[0056] At 950, at least some pins are adjusted. The controller 120 of the system 100 may adjust some of the pins 106 based on the determined changes that have to be made to the sheet of metal 150 to better conform to the desired design. In some embodiments, the controller 120 may determine the bends or deformations that should be made to conform to the desired design and may adjust at least some of the pins 106 so that at least some of the bends and or deformations are applied to the sheet of metal 150 when the sheet of metal 150 is passed through the system 100.

[0057] At 960, the sheet of metal is passed through the stands. The sheet of metal 150 may be passed through the stands 105 (including pins 106) of the system 100. Any method for moving the sheet of metal 150 through the system 100 may be used.

[0058] At 970, revised physical properties of the sheet of metal are determined. The revised properties may be determined by the controller 120 of the system 100 using the camera, for example. The properties of the sheet of metal 150 have changed due to the passing of the sheet of metal 150 through the pins 106 of the stands 105. The revised physical properties may be a revised shape.

[0059] At 980, the determined revised physical properties are compared to the desired design. The determined revised physical properties may be compared to the desired design by the controller 120. The controller 120 may then, based on the comparison, determine what additional changes to make to the sheet of metal 150 to better conform to the desired design.

[0060] At 990, at least some pins are adjusted. The controller 120 of the system 100 may adjust some of the pins based on the determined additional changes that have to be made to the sheet of metal 150 to better conform to the desired design.

[0061] At 995, the sheet of metal is again passed through the stands. The sheet of metal 150 may be passed through the stands 105 (including pins 106) of the system 100. The method 900 may then continue at 970 and repeat steps 970-995 until it is determined that the sheet of metal 150 substantially conforms to the desired design.

[0062] FIG. 10 shows an exemplary computing environment in which example embodiments and aspects may be implemented. The computing device environment is only one example of a suitable computing environment and is not intended to suggest any limitation as to the scope of use or functionality.

[0063] Numerous other general purpose or special purpose computing devices environments or configurations may be used. Examples of well-known computing devices, environments, and/or configurations that may be suitable for use include, but are not limited to, personal computers, server computers, handheld or laptop devices, multiprocessor systems, microprocessor-based systems, network personal computers (PCs), minicomputers, mainframe computers, embedded systems, distributed computing environments that include any of the above systems or devices, and the like.

[0064] Computer-executable instructions, such as program modules, being executed by a computer may be used. Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types. Distributed computing environments may be used where tasks are performed by remote processing devices that are linked through a communications network or other data transmission medium. In a distributed computing environment, program modules and other data may be located in both local and remote computer storage media including memory storage devices.

[0065] With reference to FIG. 10, an exemplary system for implementing aspects described herein includes a computing device, such as computing device 1000. In its most basic configuration, computing device 1000 typically includes at least one processing unit 1002 and memory 1004. Depending on the exact configuration and type of computing device, memory 1004 may be volatile (such as random access memory (RAM)), non-volatile (such as read-only memory (ROM), flash memory, etc.), or some combination of the two. This most basic configuration is illustrated in FIG. 10 by dashed line 1006.

[0066] Computing device 1000 may have additional features/functionality. For example, computing device 1000 may include additional storage (removable and/or non-removable) including, but not limited to, magnetic or optical disks or tape. Such additional storage is illustrated in FIG. 10 by removable storage 1008 and non-removable storage 1010.

[0067] Computing device 1000 typically includes a variety of computer readable media. Computer readable media can be any available media that can be accessed by the device 1000 and includes both volatile and non-volatile media, removable and non-removable media.

[0068] Computer storage media include volatile and non-volatile, and removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Memory 1004, removable storage 408, and non-removable storage 1010 are all examples of computer storage media. Computer storage media include, but are not limited to, RAM, ROM, electrically erasable program read-only memory (EEPROM), flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by computing device 1000. Any such computer storage media may be part of computing device 1000.

[0069] Computing device 1000 may contain communication connection(s) 1012 that allow the device to communicate with other devices. Computing device 1000 may also have input device(s) 1014 such as a keyboard, mouse, pen, voice input device, touch input device, etc. Output device(s) 1016 such as a display, speakers, printer, etc. may also be included. All these devices are well known in the art and need not be discussed at length here.

[0070] It should be understood that the various techniques described herein may be implemented in connection with hardware components or software components or, where appropriate, with a combination of both. Illustrative types of hardware components that can be used include Field-programmable Gate Arrays (FPGAs), Application-specific Integrated Circuits (ASICs), Application-specific Standard Products (ASSPs), System-on-a-chip systems (SOCs), Complex Programmable Logic Devices (CPLDs), etc. The methods and apparatus of the presently disclosed subject matter, or certain aspects or portions thereof, may take the form of program code (i.e., instructions) embodied in tangible media, such as floppy diskettes, CD-ROMs, hard drives, or any other machine-readable storage medium where, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the presently disclosed subject matter.

[0071] Although exemplary implementations may refer to utilizing aspects of the presently disclosed subject matter in the context of one or more stand-alone computer systems, the subject matter is not so limited, but rather may be implemented in connection with any computing environment, such as a network or distributed computing environment. Still further, aspects of the presently disclosed subject matter may be implemented in or across a plurality of processing chips or devices, and storage may similarly be affected across a plurality of devices. Such devices might include personal computers, network servers, and handheld devices, for example.

[0072] Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

CLAIMS

What is claimed is:

1. A method for the manufacturing of a metallic component comprising:

receiving a desired design for a metallic component by a forming system, wherein the forming system comprises a plurality of stands, and each stand comprises a plurality of pins;

receiving a sheet of metal by the forming system;

determining a shape of the sheet of metal by the forming system;

comparing the shape of the sheet of metal to the desired design by the forming system;

adjusting at least some of the plurality of pins of the plurality of stands by the forming system based on the comparison;

passing the sheet of metal through the plurality of pin stands to incrementally bend, or stretch the sheet of metal by at least some of the plurality of pins by the forming system;

determining a revised shape of the sheet of metal by the forming system after the sheet of metal has passed through the plurality of pin stands;

comparing the revised shape of the sheet of metal to the desired design by the forming system;

readjusting at least some of the plurality of pins of the plurality of stands by the forming system based on the comparison; and

passing the sheet of metal through the plurality of pin stands to incrementally bend the sheet of metal by at least some of the plurality of pins by the forming system.

2. The method of claim 1, further comprising repeatedly passing the sheet of metal through the plurality of pin stands and readjusting the at least some of the plurality of pins until the system determines that the shape of the sheet of metal matches the desired design.

3. The method of claim 1, wherein the plurality of pin stands comprise one, two, or three rows of pin stands.

4. The method of claim 3, wherein the one pin stand is used to form shapes in the metal sheet that have little change along one direction of the metal sheet.

5. The method of claim 3, wherein the two or more pin stands are used to avoid twisting the metal sheet.

6. The method of claim 3, and three pin stands are used to produce curvature along the component.

7. The method of claim 1, wherein an orientation and an angle of each of the plurality of pin stands may be adjusted.

8. The method of claim 1, wherein determining the physical properties of the sheet of metal by the forming system comprises determining the physical properties of the sheet of metal using a camera.

9. The method of claim 1, further comprising rollers or lubrication, vibration, rotation or other means to reduce friction on the pins.

10. The method of claim 1, further comprising replacing the pins with rollers.

11. A system for the manufacturing of a metallic component comprising:

one or more processors; and

a computer-readable medium with computer-executable instructions stored thereon that when executed by the one or more processors cause the system to:

receive a desired design for a metallic component, wherein the system comprises a plurality of stands, and each stand comprises a plurality of pins;

receive a sheet of metal;

determine a shape of the sheet of metal;

compare the shape of the sheet of metal to the desired design;

adjust at least some of the plurality of pins of the plurality of stands based on the comparison;

pass the sheet of metal through the plurality of pin stands to incrementally bend the sheet of metal by at least some of the plurality of pins;

determine a revised shape of the sheet of metal after the sheet of metal has passed through the plurality of pin stands;

compare the revised shape of the sheet of metal to the desired design;

readjust at least some of the plurality of pins of the plurality of stands based on the comparison; and pass the sheet of metal through the plurality of pin stands to incrementally bend the sheet of metal by at least some of the plurality of pins.

12. The system of claim 11, further comprising repeatedly passing the sheet of metal through the plurality of pin stands and readjusting the at least some of the plurality of pins until the system determines that the shape of the sheet of metal matches the desired design.

13. The system of claim 11, wherein the plurality of pin stands comprise one, two, or three pin stands.

14. The system of claim 13, wherein the one pin stand is used to form shapes in the metal sheet that have little change along one direction of the metal sheet.

15. The system of claim 13, wherein the two pin stands are used to avoid twisting the metal sheet.

16. The system of claim 13, and three pin stands are used to produce curvature along the component.

17. The system of claim 11, wherein an orientation and an angle of each of the plurality of pin stands may be adjusted.

18. The system of claim 11, wherein determining the physical properties of the sheet of metal by the forming system comprises determining the physical properties of the sheet of metal using a camera.

19. The system of claim 11, further comprising rollers or lubrication on the pins.

20. A computer-readable medium with computer-executable instructions stored thereon that when executed by one or more processors cause the one or more processors to:

receive a desired design for a metallic component, wherein a forming system comprises a plurality of stands, and each stand comprises a plurality of pins;

receive a sheet of metal;

determine a shape of the sheet of metal;

compare the shape of the sheet of metal to the desired design;

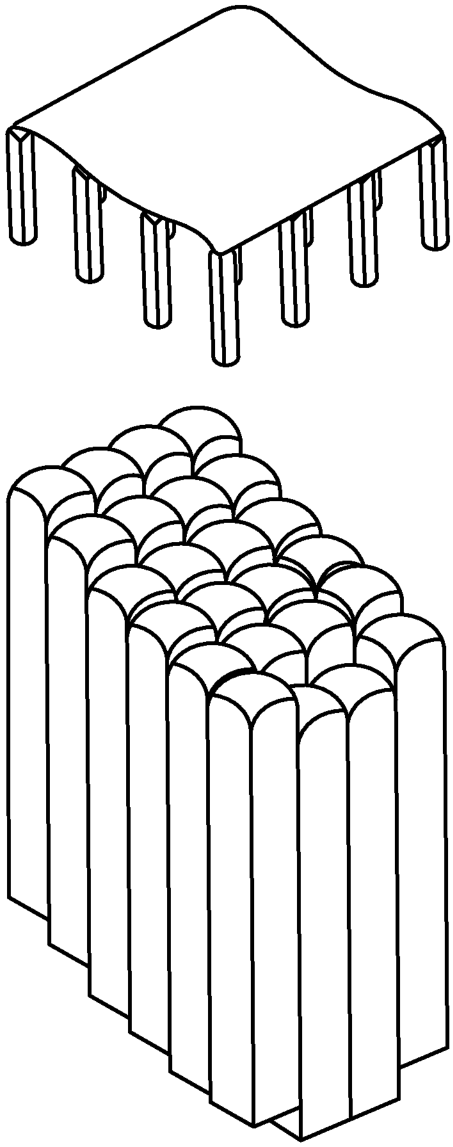
adjust at least some of the plurality of pins of the plurality of stands based on the comparison;

pass the sheet of metal through the plurality of pin stands to incrementally bend the sheet of metal by at least some of the plurality of pins by the forming system;

determine a revised shape of the sheet of metal after the sheet of metal has passed through the plurality of pin stands;

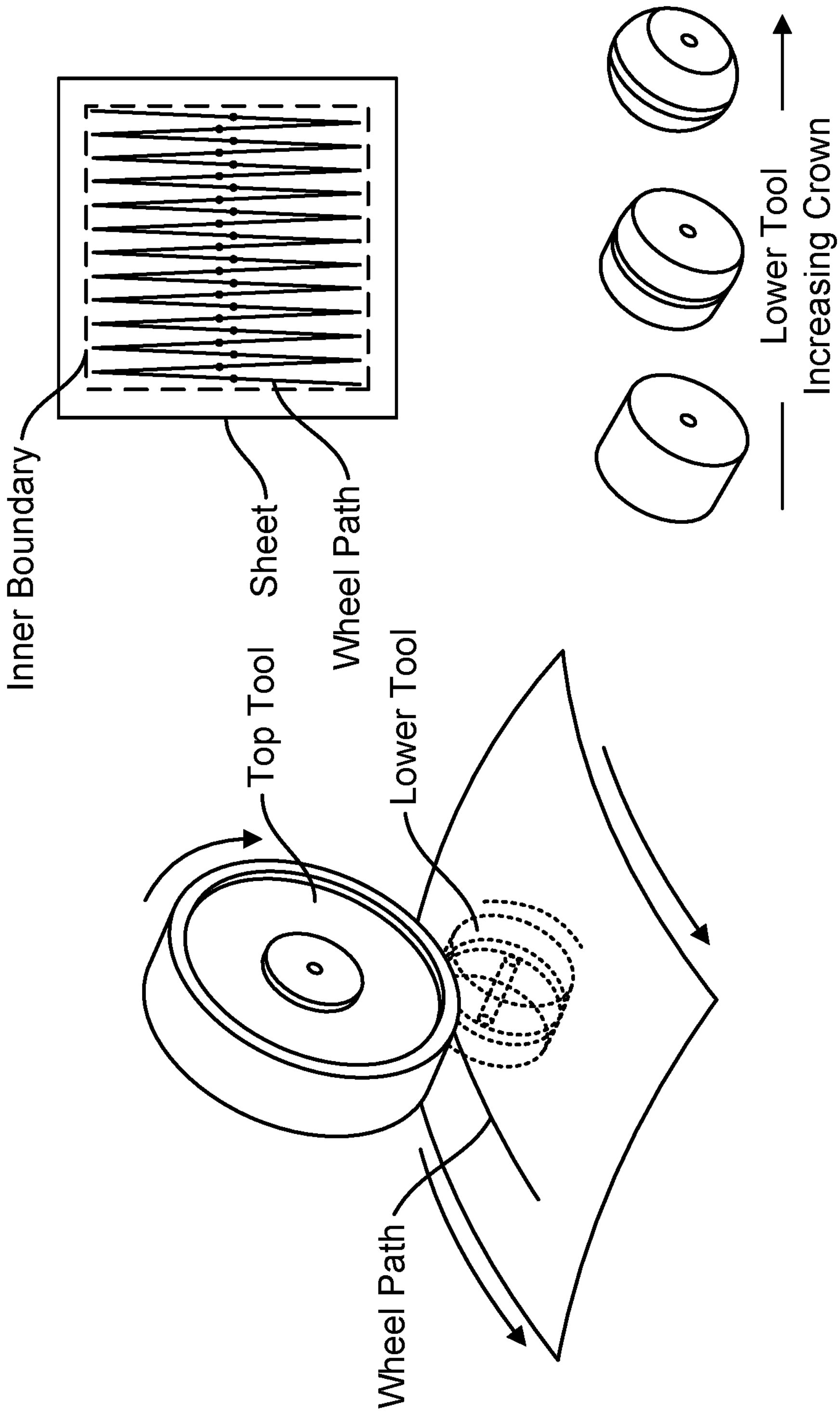
compare the revised shape of the sheet of metal to the desired design;

readjust at least some of the plurality of pins of the plurality of stands based on the comparison; and pass the sheet of metal through the plurality of pin stands to incrementally bend the sheet of metal by at least some of the plurality of pins.

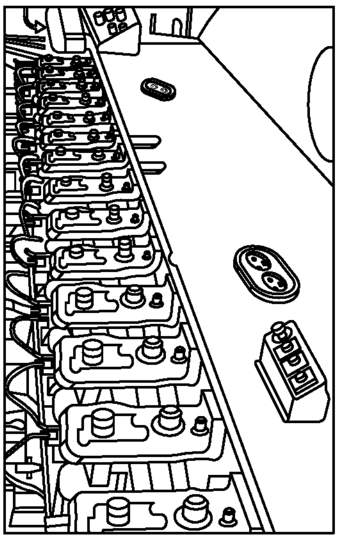


(Prior Art)

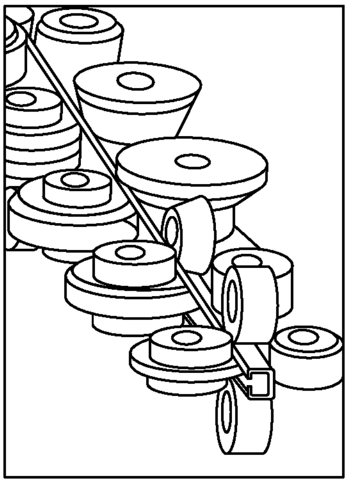
FIG. 1



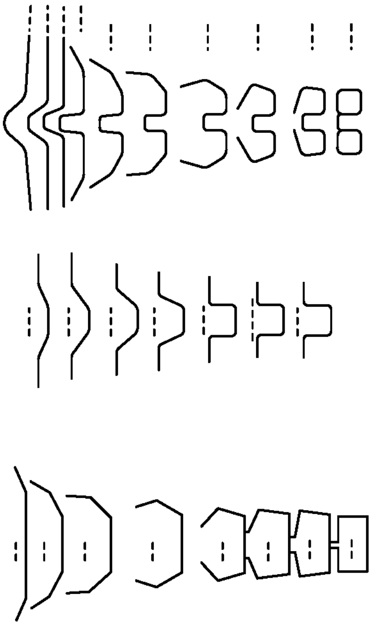
(Prior Art)
FIG. 2



(Prior Art)
FIG. 3A



(Prior Art)
FIG. 3B



(Prior Art)
FIG. 3C

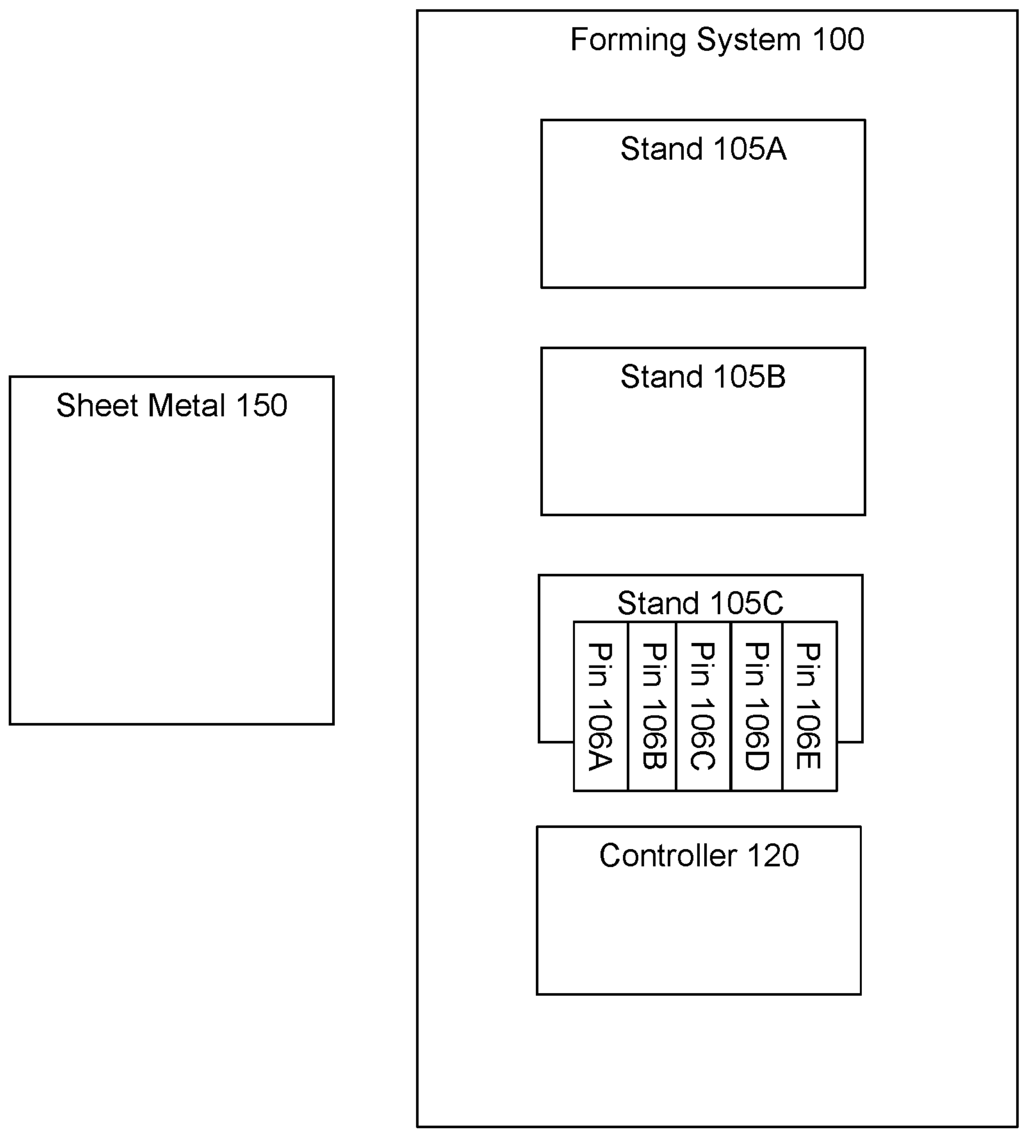

Forming System 100
Stand 105A
Stand 105B
Stand 105C
Pin 106A
Pin 106B
Pin 106C
Pin 106D
Pin 106E
Controller 120
Sheet Metal 150

FIG. 4

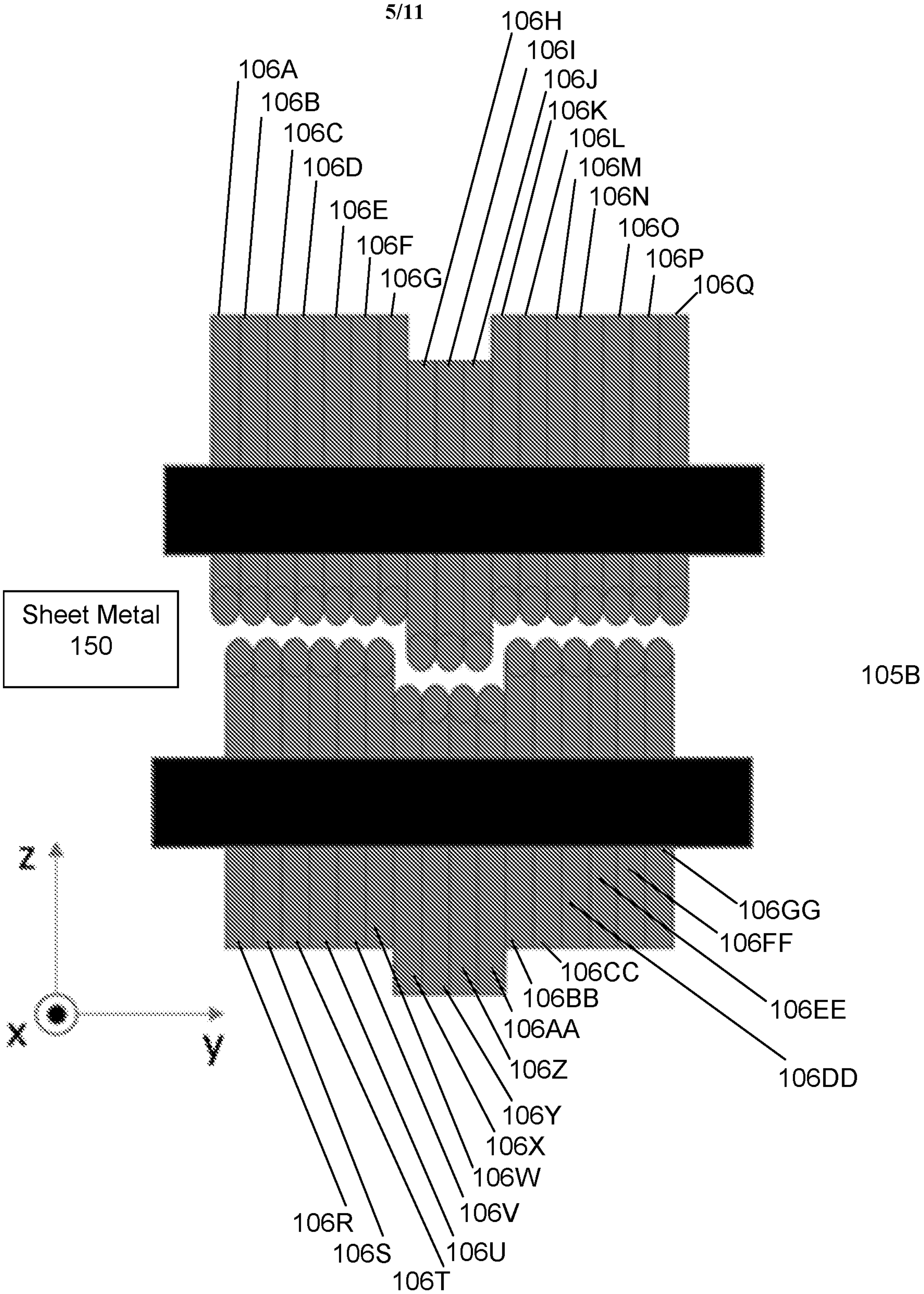

106A
106B
106C
106D
106E
106F
106G
106H
106I
106J
106K
106L
106M
106N
106O
106P
106Q
Sheet Metal 150
105B
Z
X
Y
106GG
106FF
106CC
106BB
106EE
106AA
106Z
106DD
106Y
106X
106W
106V
106R
106S
106U
106T

FIG. 5

105

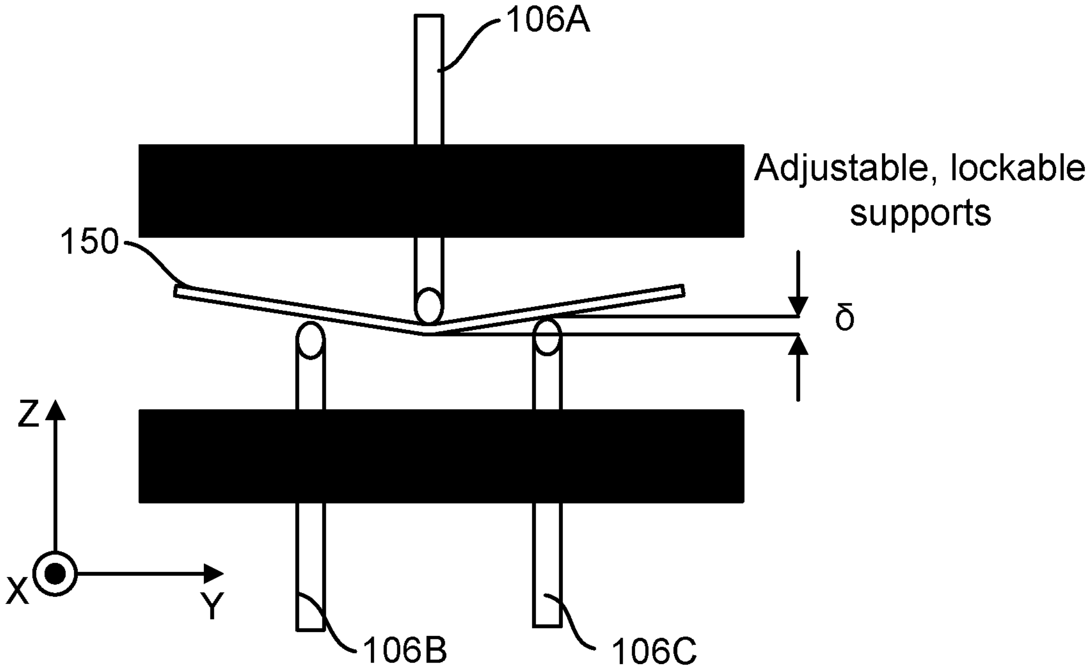


FIG. 6A

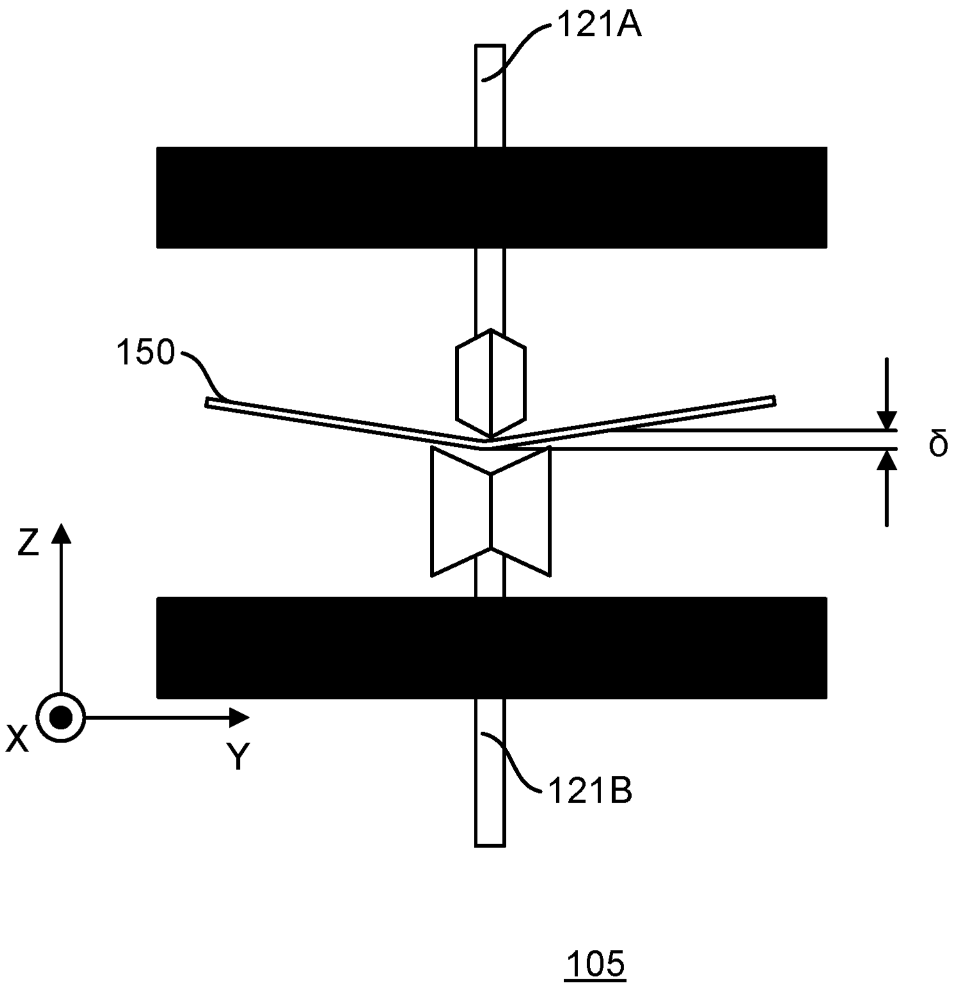
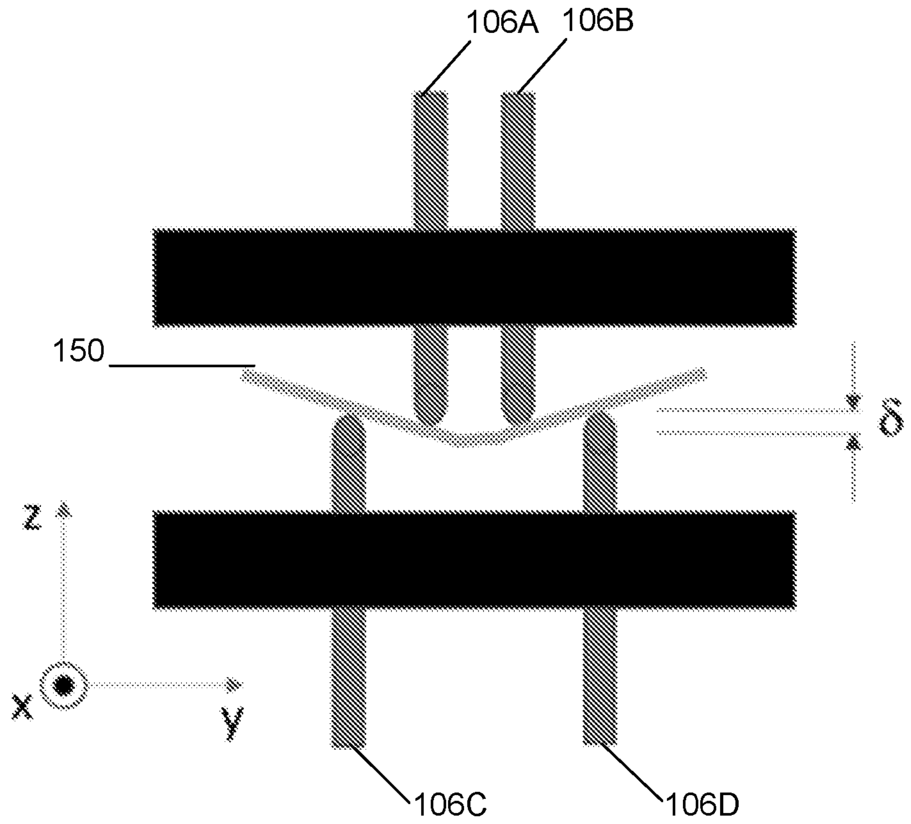
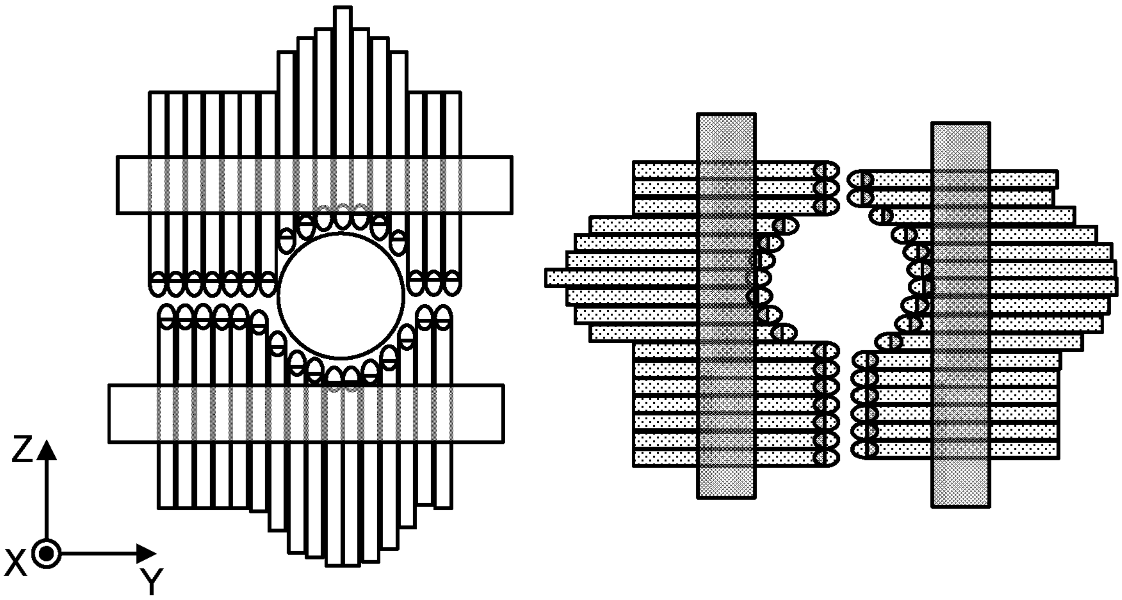


FIG. 6B

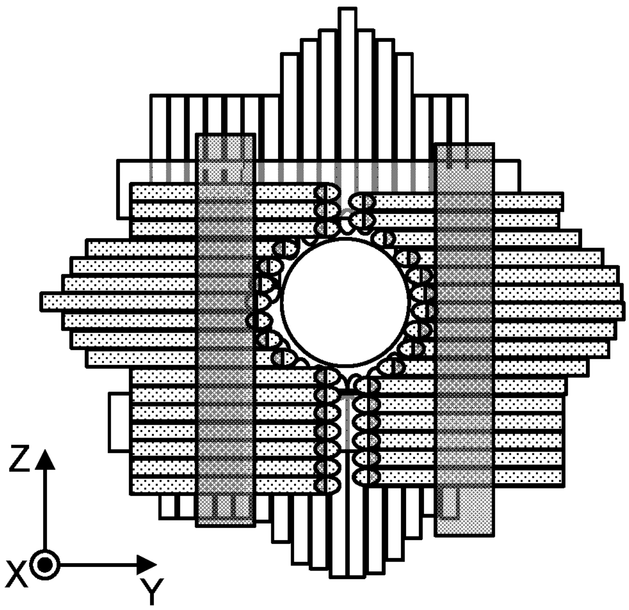


105

FIG. 7



105A 105B



105C

FIG. 8

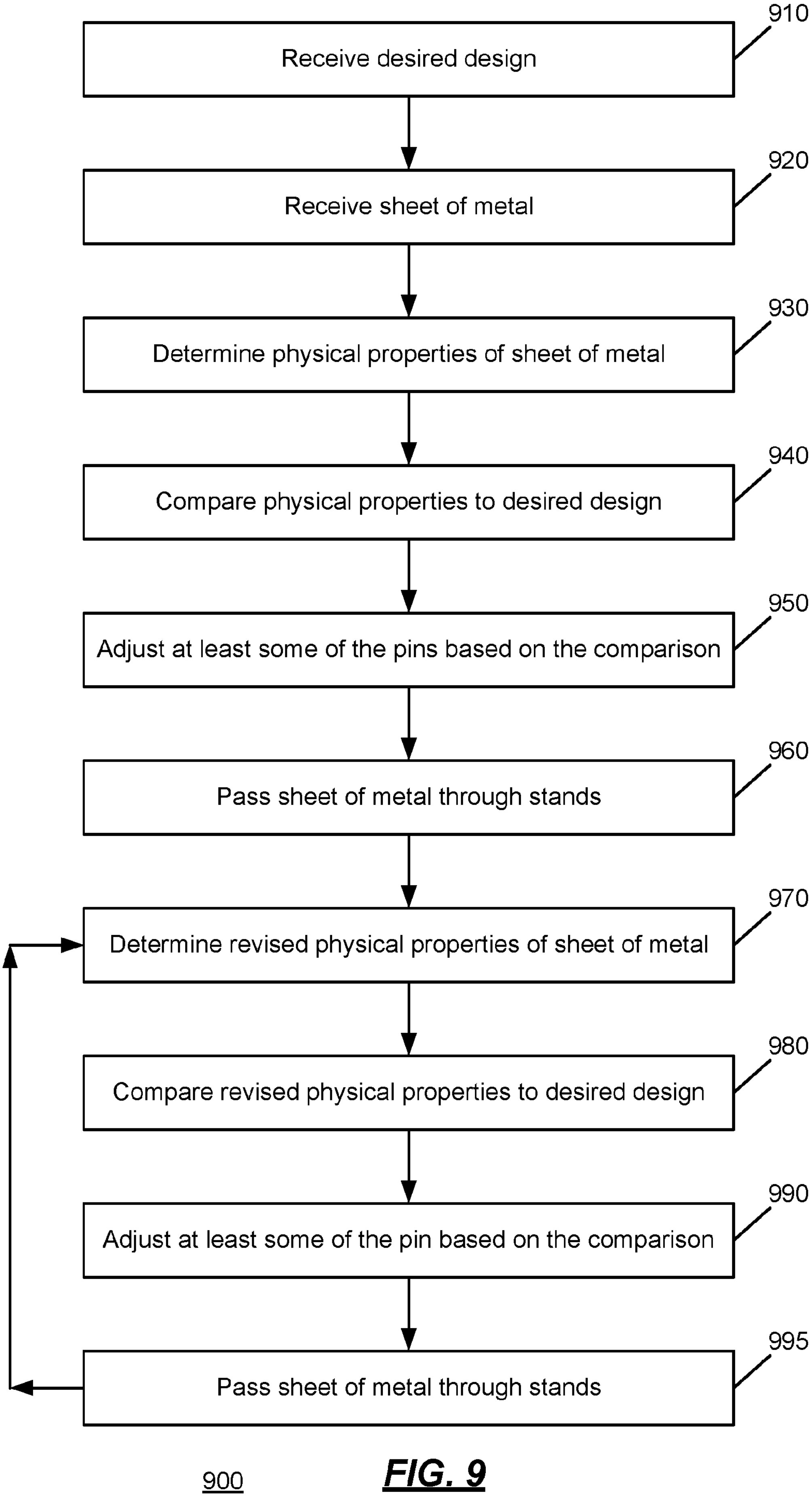
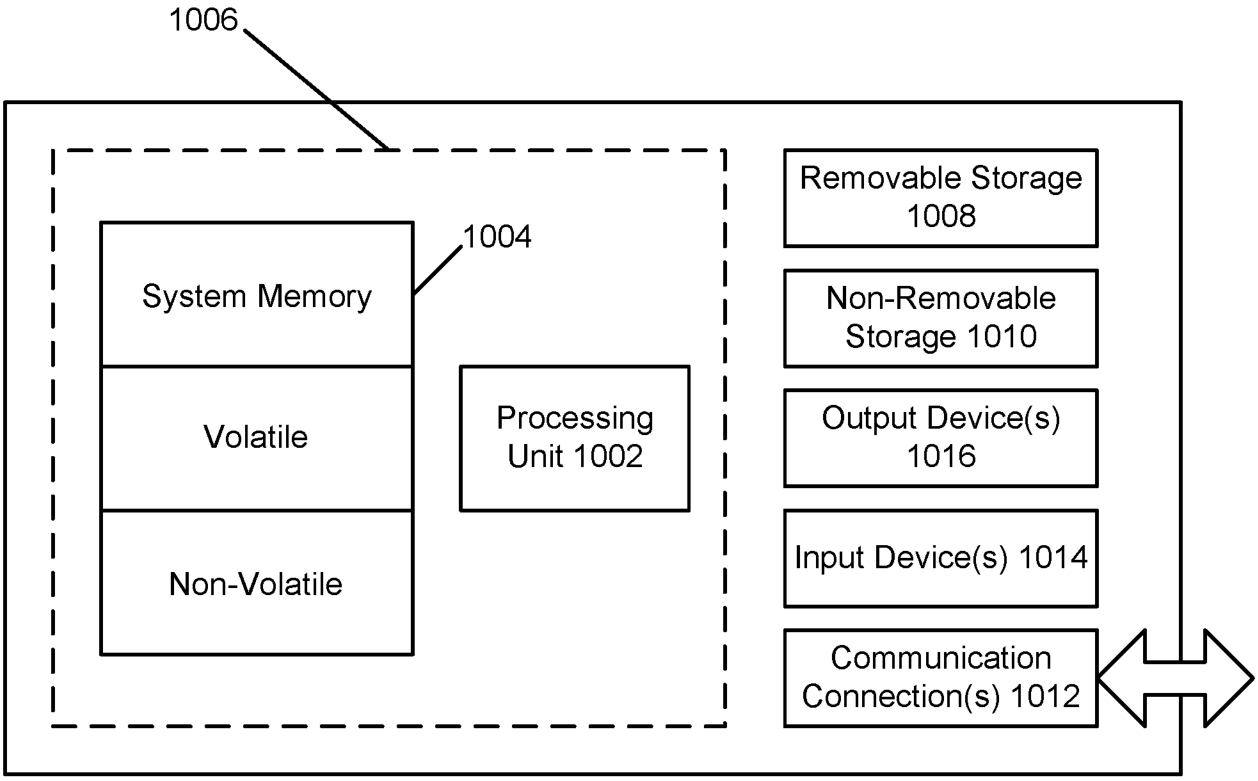

Receive desired design
910
Receive sheet of metal
920
Determine physical properties of sheet of metal
930
Compare physical properties to desired design
940
Adjust at least some of the pins based on the comparison
950
Pass sheet of metal through stands
960
Determine revised physical properties of sheet of metal
970
Compare revised physical properties to desired design
980
Adjust at least some of the pin based on the comparison
990
Pass sheet of metal through stands
995
900

FIG. 9


1006
1004
System Memory
Volatile
Non-Volatile
Processing Unit 1002
Removable Storage 1008
Non-Removable Storage 1010
Output Device(s) 1016
Input Device(s) 1014
Communication Connection(s) 1012

1000

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 24/13300

A. CLASSIFICATION OF SUBJECT MATTER
IPC - INV. B21D 11/20, B21D 31/00 (2024.01)
ADD.

CPC - INV. B21D 11/20, B21D 31/005

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)
See Search History document

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/0030362 A1 (PAIK) 04 February 2010 (04.02.2010), entire document, especially Title, Abstract, Figs 1-3	1-20
A	US 2009/0107199 A1 (LI et al.) 30 April 2009 (30.04.2009), entire document, especially Title, Abstract, Figs. 26A, 26B, 27A, 27B, para. [0059]	1-20
A	US 2016/0221053 A1 (PUSAN NATIONAL INDUSTRY-UNIVERSITY COOPERATION FOUNDATION) 04 August 2016 (04.08.2016), entire document, especially Abstract, Figs. 3, 4, 7, and 10-17	1-20
A	US 2020/0353526 A1 (FIGUR MACHINE TOOLS LLC) 12 November 2020 (12.11.2020), entire document, especially Abstract, Figs. 1A-5	1-20
A	WO 2010/094953 A1 (FORMTEXX LIMITED et al.) 26 August 2010 (26.08.2010), entire document, especially Abstract, Figs. 1A and 5A	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
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 April 2024	MAY 16 2024
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Kari Rodriquez Telephone No. PCT Helpdesk: 571-272-4300