

FIG. 3

SYSTEM AND METHOD FOR ALIGNING A WORKPIECE FOR CUTTING

BACKGROUND

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application Serial No. 62/848096 filed on May 15, 2019, the content of which is relied upon and incorporated herein by reference in its entirety.

FIELD OF THE DISCLOSURE

[0002] Among other things, the present disclosure relates to cutting a workpiece, such as a sheet of glass or metal.

DESCRIPTION OF RELATED ART

[0003] Glass or other materials can be produced for applications in which the precision of the final geometry of the workpiece is of paramount importance. A workpiece is often moved, rotated, or transferred between machines for different operations, one of which can include a cutting process. Such adjustments introduce variation into the manufacturing process, and can result in a final product with imprecise and undesirable geometry.

[0004] One existing technique for improving geometry precision includes ensuring that the workpiece is perfectly aligned with a cutting apparatus before the cutting process. However, repeatability is difficult to achieve and moving the workpiece to a position of perfect alignment is a time consuming process which results in decreased productivity. Preventative maintenance can improve alignment repeatability, but also leads to increased down-time for equipment and additional material and labor costs.

SUMMARY

[0005] Features disclosed herein enable minimization or elimination of the undesirable effects of misalignment prior to cutting a workpiece. A cutting assembly can compensate for variation in workpiece alignment in order to ensure a repeatable cutting process and adherence to strict tolerance standards.

[0006] A cutting assembly can include a carriage supporting a cutting head. The carriage can be longitudinally mobile and the cutting head can be transversely mobile along the carriage. A method of cutting a workpiece can include: determining a positioning angle defined between the workpiece and the cutting assembly; determining a cut path along the workpiece based on the positioning angle; and following the cut path with the cutting head by longitudinally moving the carriage while transversely moving the cutting head along the carriage such that the cutting head experiences simultaneous longitudinal and transverse motion.

[0007] A cutting assembly can include a carriage supporting a cutting head. The cutting assembly can be configured for longitudinal relative motion between the workpiece and the carriage, and the cutting head can be transversely mobile along the carriage. A method of cutting a workpiece can include: determining a positioning angle defined between the workpiece and the cutting assembly; determining a cut path along the workpiece based on the positioning angle; and following the cut path with the cutting head by applying longitudinal relative motion between the workpiece and the carriage while transversely moving the cutting head along the carriage.

[0008] A cutting assembly can include a carriage supporting first and second cutting heads. The carriage can be longitudinally mobile, and the first and second cutting heads can be independently transversely mobile along the carriage. A method of cutting a workpiece can include: determining a positioning angle defined between the workpiece and the cutting assembly; determining first and second cut paths along the workpiece based on the positioning angle; following, with the first cutting head, the first cut path by longitudinally moving the carriage while transversely moving the first cutting head along the carriage such that the first cutting head experiences simultaneous longitudinal and transverse motion; and following, with the second cutting head, the second cut path by longitudinally moving the carriage while transversely moving the second cutting head along the carriage such that the second cutting head experiences simultaneous longitudinal and transverse motion. The first cutting head can begin following the first

cut path before the second cutting head begins following the second cut path, the second cutting head can begin following the second cut path before the first cutting head completes the first cut path, and the first cutting head can complete the first cut path before the second cutting head completes the second cut path.

[0009] A system for cutting a workpiece can include a cutting assembly and a processing system. The cutting assembly can include a carriage supporting a cutting head. The carriage can be configured for longitudinal movement, and the cutting head can be configured for transverse movement along the carriage. The processing system can include one or more processors configured to: determine a positioning angle defined between the workpiece and the cutting assembly; determine a cut path along the workpiece based on the positioning angle; and cause the cutting head to follow the cut path by causing the carriage to move longitudinally while causing the cutting head to move transversely along the carriage such that the cutting head experiences simultaneous longitudinal and transverse motion.

BRIEF DESCRIPTION OF DRAWINGS

[0010] The above summary and the below detailed description of illustrative embodiments may be read in conjunction with the appended Figures. The Figures show some of the illustrative embodiments discussed herein. The relative dimensions shown in the Figures can serve as original support for claimed features. As further explained below, the claims are not limited to the illustrative embodiments and are therefore not limited to any dimensions shown in the Figures unless otherwise explicit. For clarity and ease of reading, Figures may omit views of certain features.

[0011] Figures 1A–1C schematically illustrate an exemplary method of cutting a workpiece.

[0012] Figure 2 schematically illustrates exemplary desired and undesired cutting paths on a misaligned workpiece.

[0013] Figure 3 schematically illustrates an exemplary cutting assembly in relation to a misaligned workpiece.

[0014] Figure 4 schematically illustrates an exemplary cutting assembly where the first cutting head is at an intermediate point along the first cutting path.

[0015] Figure 5 schematically illustrates an exemplary cutting assembly where both the first and second cutting heads are at intermediate points along their respective cutting paths.

[0016] Figure 6 schematically illustrates an exemplary cutting assembly where the first cutting head has completed its respective cutting path.

[0017] Figure 7 schematically illustrates an exemplary cutting assembly where the first and second cutting heads have both completed their respective cutting paths.

[0018] Figure 8 is a block diagram of an exemplary method of cutting a workpiece.

[0019] Figure 9 is a block diagram of an exemplary processing system for performing the methods of Figure 8.

DETAILED DESCRIPTION

[0020] The present application discloses illustrative (i.e., example) embodiments. The claimed inventions are not limited to the illustrative embodiments. Therefore, many implementations of the claims will be different than the illustrative embodiments. Various modifications can be made to the claimed inventions without departing from the spirit and scope of the disclosure. The claims are intended to cover implementations with such modifications.

[0021] At times, the present application employs various directional terms (e.g., front, back, top, bottom, left, right, longitudinal, transverse, vertical, etc.) to give the reader context when viewing the Figures. The claimed inventions are not limited to the orientations shown in the Figures. Any absolute term (e.g., high, low, etc.) can be understood as disclosing a corresponding relative term (e.g., higher, lower, etc.). Referring to the Figures, depth along the X-axis can be “longitudinal”, depth along the Y-axis can be “transverse”, and depth along the Z-axis (unshown, but normal to the X–Y plane) can be “vertical”. In some embodiments, the X, Y, and Z-axes are consistent across the Figures.

[0022] Figures 1A–C generally illustrate cutting a workpiece 100 (also called a substrate, a panel, a plate, etc.) from a larger first geometry 100A to an intermediate second geometry 100B, then from the intermediate second geometry 100B to a smaller third geometry 100C. As further discussed below, technology disclosed in the present application enables accurate cuts even when workpiece 100 is misaligned with respect to the cutting assembly.

[0023] Referring to Figure 1A, workpiece 100 can begin with larger first geometry 100A. To reduce the size, or improve the shape of workpiece 100, a cutting assembly 300 (labeled in Figure 3) can cut along parallel first and second cutting paths 102, 104.

[0024] Referring to Figure 1B, workpiece 100 (now rotated clockwise 90° in the X-Y plane with respect to Figure 1A) has attained intermediate second geometry 100B. First cutting path 102 has created first side 112. Second cutting path 104 has created second side 114. The same or a similar cutting assembly 300 can now cut along parallel third and fourth cutting paths 106, 108 present in second geometry 100B.

[0025] Referring to Figure 1C, workpiece 100 has attained smaller third geometry 100C. Third cutting path 106 has created third side 116. Fourth cutting path 108 has created fourth side 118.

[0026] Workpiece 100 can be misaligned with respect to the Y-axis prior to cutting (e.g., before cutting along any of the previously mentioned cutting paths). As shown in Figures 2 and 3, workpiece 100 can define a positioning angle 202 with respect to the Y-axis. If cutting assembly 300 is transversely aligned and no corrections are made, then cutting assembly 300 can cut along undesirable first and second cutting paths 212, 214 defining undesirable (e.g., non 90°) corners 216 (labeled in Figure 2).

[0027] Embodiments of the present disclosure enable cutting assembly 300 to follow desirable first and second cutting paths 222, 224 defining desirable (e.g., 90°) corners 218, even when workpiece 100 defines positioning angle 202 with respect to the Y-axis. Desirable first and second cutting paths 222, 224 can respectively define first and second cutting angles 222A, 224A with respect to the X or Y-axes based on the size of positioning angle 202. In the embodiments illustrated in the Figures, first and second cutting angles 222A, 224A can each have a size equal to positioning angle 202.

[0028] Referring to Figure 3, cutting assembly 300 can include a carriage 302 and first and second cutting heads 312, 314 mounted thereto. In some embodiments, carriage 302 is configured to only move along the X-axis (i.e., longitudinally), while first and second cutting heads 312, 314 can independently transversely move along carriage 302. By longitudinally moving carriage 302 along the X-axis while simultaneously transversely moving first and second cutting heads 312, 314 along carriage 302 (and thus along the Y-axis), cutting heads 312, 314 can follow first and second cutting paths 222, 224, thus compensating for cutting errors (e.g., undesirable first and second cutting paths 212, 214) that positioning angle 202 would otherwise cause.

[0029] Referring to Figure 3, workpiece 100 can be panel including metal, glass, wood, plastic, ceramic, or composite material. As shown in the Figures, workpiece 100 can have a boxed three-dimensional geometry with a rectangular profile in the X–Y plane. In other embodiments (not shown), workpiece 100 can have any geometry (e.g., a spherical geometry, a pyramid-shaped geometry, etc.). Similarly, although desirable first and second cutting paths 222, 224 are shown as being parallel segments defining 90° corners 218, desirable first and second cutting paths 222, 224 can have any desired geometry (e.g., each can define an “S” shape in the X–Y plane). Workpiece 100 of Figure 3 can be at any stage during a manufacturing process (e.g., in first geometry 100A, second geometry 100B, or third geometry 100C).

[0030] As further discussed below, a processing system 900 including one or more processors 901 can be configured to control cutting assembly 300 by, for example, issuing electronic commands to motors (i.e., electronic actuators) disposed therein. In some embodiments, processing system 900 can include the electronic control features of cutting assembly 300. Processing system 900 can be configured to perform (e.g., cause) any method or operation disclosed herein such that every function disclosed in the present application can be performed automatically and without human intervention. Processing system 900 is further discussed below with reference to Figure 9.

[0031] As shown in Figure 3, cutting assembly 300 can include a transversely extending carriage 302 (i.e., a carriage extending along the Y-axis) configured to translate (via one or more unshown motors) in the longitudinal direction (i.e., along the X-axis). One or more cutting heads can be moveably mounted to carriage 302 including a first cutting head 312 and a second cutting head 314. Cutting heads 312, 314 can be configured to transversely slide along carriage 302. By longitudinally actuating carriage 302 and transversely actuating cutting heads 312, 314 along carriage 302, processing system 900 can produce the cumulative effect of moving cutting heads 312, 314 in a direction slanted with respect to both the X and Y-axes (e.g., along desirable first and second cutting paths 222, 224). In order to pierce workpiece 100, cutting heads 312, 314 can include one or more lasers, one or more water jets, one or more drill bits, one or more scribe wheels, etc.

[0032] In some embodiments, processing system 900 can independently switch cutting heads 312, 314 between an active mode (also called an engaged mode) where the respective cutting head is capable of piercing workpiece 100 (e.g., where the respective laser is on) and a passive mode (also called a disengaged mode or a safety mode), where the respective cutting head is incapable of piercing workpiece 100. First cutting head 312

can be in the active mode while second cutting head 314 is in the passive mode and vice-versa.

[0033] Figure 8 shows a method of using cutting assembly 300 to cut workpiece 100 along desirable first and second cutting paths 222, 224. For the reasons stated above, processing system 900 can be configured to automatically perform (e.g., cause) each and every feature of the method in Figure 8. At block 802, workpiece 100 can be clamped or otherwise stopped in the position of Figure 3 to define a nonzero positioning angle 202 with respect to the transverse (i.e., Y) axis.

[0034] At block 804, processing system 900 can receive a desired final geometry of workpiece 100 (i.e., the post-cutting geometry) (e.g., the dimensions of desirable first and second cutting paths 222, 224 with respect to the local coordinate system of workpiece 100). In the embodiment of Figure 3, processing system 900 receives an instruction to execute two parallel cuts across the complete span of workpiece 100 where each cut is offset an arbitrary dimension 352 (e.g., 10mm) from a transversely extending workpiece side 362 (although sides 362 are slanted with respect to the global coordinate system of Figure 3, sides 362 transversely extend in the local coordinate system of workpiece 100).

[0035] At block 806, processing system 900 can capture the dimensions of (i.e., measure) workpiece 100. Block 806 can include, for example, capturing one or more images of workpiece 100 with one or more cameras (not shown) of processing system 900. At block 808, processing system 900 can determine positioning angle 202 based on the measured dimensions of workpiece 100 (e.g., by analyzing the captured images). In some embodiments, processing system 900 can apply a feature extraction program to identify the side of workpiece 100 most closely aligned with carriage 302 (e.g., workpiece side 364 in Figure 3), then compute positioning angle 202 as the angle between the identified side and the transverse (i.e., Y) axis.

[0036] At block 810, processing system 900 can determine (e.g., calculate, lookup, etc.) desirable first and second cutting paths 222, 224 based on the desired final geometry of workpiece 100 received in block 804 (e.g., the desired cutting dimensions in the local coordinate system of workpiece 100) and positioning angle 202. At block 812, processing system 900 can cause cutting assembly 300 to assume the position shown in Figure 3 where one of the cutting heads (e.g., first cutting head 312) is positioned directly vertically above the beginning of a respective desirable cutting path (e.g., desirable first cutting path 222). At block 814, processing system 900 can switch first cutting head 312 from the passive mode to the active mode as discussed above.

[0037] At block 816, processing system 900 can sweep first cutting head 312 along desirable first cutting path 222 by longitudinally translating carriage 302 while transversely translating first cutting head 312 along the transverse axis of carriage 302.

[0038] Referring to Figure 4, processing system 900 can transversely translate first cutting head 312 along the axis of carriage 302 as a trigonometric function of the positioning angle 202 and the longitudinal distance 402 disposed between the current position of first cutting head 312 and the initial longitudinal position of first cutting head in block 812. As a result, processing system 900 can compute the transverse distance 404 disposed between the current position of first cutting head 312 and the initial transverse position of first cutting head in block 812 based on the following trigonometric formula: $[\text{transverse distance } 404] = [\text{longitudinal distance } 402] * [\tan(\text{positioning angle } 202)]$. Put differently, processing system 900 can transversely actuate first cutting head 312 at a speed according to (i.e., based on) the following trigonometric formula: $[\text{transverse speed of first cutting head } 312 \text{ along transverse axis of carriage } 302] = [\text{longitudinal speed of carriage } 302] * [\tan(\text{positioning angle } 202)]$. Therefore, the current transverse speed of first cutting head 312 can be a function of the current longitudinal speed of carriage 302 and positioning angle 202.

[0039] At block 818, and as shown in Figure 4, processing system 900 can position second cutting head 314 directly vertically above the beginning of desirable second cutting path 224. At block 820, processing system 900 can switch second cutting head 314 from the passive mode to the active mode to begin severing workpiece 100 along desirable second cutting path 224. Blocks 818 and 820 can occur simultaneously. Blocks 818 and 820 can occur in parallel with block 816 such that carriage 302 remains in perpetual motion from the point in time shown in Figure 3 until the point in time shown in Figure 7.

[0040] At block 822, processing system 900 can sweep second cutting head 314 along desirable second cutting path 224 by longitudinally translating carriage 302 while transversely translating second cutting head 314 along the transverse axis of carriage 302.

[0041] Referring to Figure 5, processing system 900 can transversely translate second cutting head 314 along the axis of carriage 302 as a trigonometric function of the positioning angle 202 and the longitudinal distance 502 disposed between the current position of second cutting head 314 and the initial longitudinal position of second cutting head in block 818. As a result, processing system 900 can compute the transverse distance 504 disposed between the current position of second cutting head 314 and the initial

transverse position of second cutting head in block 818 based on the following trigonometric formula: [transverse distance 504] = [longitudinal distance 502] * [tan(positioning angle 202)]. Put differently, processing system 900 can transversely actuate second cutting head 314 at a speed according to (i.e., based on) the following trigonometric formula: [transverse speed of second cutting head 314 along transverse axis of carriage 302] = [longitudinal speed of carriage 302] * [tan(positioning angle 202)]. Therefore, the current transverse speed of second cutting head 314 can be a function of the current longitudinal speed of carriage 302 and positioning angle 202.

[0042] At block 824, processing system 900 can detect (i.e., determine) that first cutting head 312 has reached the terminal point of desirable first cutting path 222 (shown in Figure 6), thus completely severing first material chunk 602 from workpiece 100. At block 826, processing system 900 can, based on the detection, switch first cutting head 312 from the active mode to the passive mode. Processing system 900 can perform blocks 824 and 826 simultaneously.

[0043] At block 828, processing system 900 can detect (i.e., determine) that second cutting head 314 has reached the terminal point of desirable second cutting path 224 (shown in Figure 7), thus completely severing second material chunk 604 from workpiece 100. At block 830, processing system 900 can, based on the detection, switch second cutting head 314 from the active mode to the passive mode. Processing system 900 can perform blocks 828 and 830 simultaneously. Processing system 900 can keep carriage 302 in perpetual longitudinal motion (e.g., moving at a constant longitudinal rate of 100cm/s) from at least block 812 through block 830.

[0044] It will be understood by those of skill in the art that, depending on the magnitude of positioning angle 202, a time duration between a particular step related to the first cutting head (e.g., step 812 in Figure 8) and a similar step related to the second cutting head (e.g., step 818 in Figure 8) may be minimal and/or imperceptible. Therefore, the exemplary embodiment of the present disclosure is applicable regardless of the magnitude of positioning angle 202.

[0045] Referring to Figure 9, processing system 900 can include one or more processors 901, memory 902, one or more input-output devices 903, one or more sensors 904, one or more user interfaces 905, and one or more actuators 906. Processing system 900 can include components disposed within the housing of cutting assembly 300. Processing system 900 can be distributed. For example, some elements of processing system 900 can be disposed within the housing of cutting assembly 300 while other

elements of processing system 900 can be disposed in another location (e.g., at a remote server, in a mobile device, etc.).

[0046] Processors 901 may include one or more distinct processors, each having one or more cores. Each of the distinct processors may have the same or different structure. Processors 901 may include one or more central processing units (CPUs), one or more graphics processing units (GPUs), circuitry (e.g., application specific integrated circuits (ASICs)), digital signal processors (DSPs), and the like. Processors 901 may be mounted on a common substrate or to different substrates.

[0047] Processors 901 are configured to perform a certain function, method, or operation at least when one of the one or more of the distinct processors is capable of executing code, stored on memory 902 embodying the function, method, or operation. Processors 901 can be configured to perform any and all functions, methods, and operations disclosed herein without human intervention. Therefore, any one or all of the functions, methods, and operations disclosed herein can occur automatically.

[0048] For example, when the present disclosure states that processing system 900 performs/may perform task “X”, such a statement conveys that processing system 900 may be configured to perform task “X”. Similarly, when the present disclosure states that task “X” is performed, such a statement conveys that the processing system 900 of the respective may be configured to perform task “X”. Processing system 900 is configured to perform a function, method, or operation at least when processors 901 are configured to do the same.

[0049] Memory 902 may include volatile memory, non-volatile memory, and any other medium capable of storing data. Each of the volatile memory, non-volatile memory, and any other type of memory may include multiple different memory devices, located at multiple distinct locations and each having a different structure. Examples of memory 902 include a non-transitory computer-readable media such as RAM, ROM, flash memory, EEPROM, any kind of optical storage disk such as a DVD, a Blu-Ray® disc, magnetic storage, holographic storage, an HDD, an SSD, any medium that may be used to store program code in the form of instructions or data structures, and the like. Any and all of the methods, functions, and operations described in the present application may be fully embodied in the form of tangible and/or non-transitory machine-readable code saved in memory 902.

[0050] Input-output devices 903 can include any component for trafficking data such as ports, antennas (i.e., transceivers), printed conductive paths, and the like. Input-

output devices 903 can enable wired communication via USB®, DisplayPort®, HDMI®, Ethernet, and the like. Input-output devices 903 can enable electronic, optical, magnetic, and holographic, communication with suitable memory 903. Input-output devices 903 can enable wireless communication via WiFi®, Bluetooth®, cellular (e.g., LTE®, CDMA®, GSM®, WiMax®, NFC®), Gprocessing system, and the like. Input-output devices 903 can include wired and/or wireless communication pathways.

[0051] Sensors 904 can capture physical measurements of environment and report the same to processors 901. Examples of sensors 904 include cameras used to measure (i.e., determine) positioning angle 202. User interface 905 can include displays (e.g., LED touchscreens (e.g., OLED touchscreens), physical buttons, speakers, microphones, keyboards, and the like. Actuators 906 can enable processors 901 to control mechanical forces. For example, actuators may be electronically controllable motors (e.g., motors for moving first and second cutting heads 312, 314, motors for longitudinally translating carriage 302, etc.)

CLAIMS

We claim:

1. A method of cutting a workpiece, the method comprising:
determining a positioning angle defined between the workpiece and a cutting assembly, the cutting assembly comprising a carriage supporting a cutting head, the carriage being longitudinally mobile and the cutting head being transversely mobile along the carriage;
determining a cut path along the workpiece based on the positioning angle; and
following the cut path with the cutting head by longitudinally moving the carriage while transversely moving the cutting head along the carriage such that the cutting head experiences simultaneous longitudinal and transverse motion.
2. The method of claim 1, wherein the workpiece is a rectangular panel, the cut path is parallel with at least one minor side of the workpiece, and the cut path defines a non-zero angle with respect to both the transverse and longitudinal directions.
3. The method of claim 1, wherein the carriage moves longitudinally, but not transversely, while the cutting head is following the cut path.
4. The method of claim 3, wherein the cut path is a line segment extending from a first major side of the workpiece to an opposing second major side of the workpiece such that by following the cut path, the cutting head severs the workpiece into discrete and detached portions.
5. The method of claim 4, wherein the workpiece is a rectangular panel comprising glass, ceramic, or metal and the cut path is perpendicular to both the first and second major sides of the workpiece.
6. The method of claim 1, wherein the cut path defines a cut angle with respect to the longitudinal axis, a magnitude of the cut angle equaling a magnitude of the positioning angle.

7. The method of claim 1 comprising determining the cut path based on a trigonometric function of the positioning angle.

8. The method of claim 1 further comprising:
prior to determining the positioning angle, cutting the workpiece in the longitudinal direction; and
rotating the workpiece 90° about an axis perpendicular to the longitudinal direction.

9. A method of cutting a workpiece, the method comprising:
determining a positioning angle defined between the workpiece and a cutting assembly, the cutting assembly comprising a carriage supporting a cutting head, the cutting assembly being configured for longitudinal relative motion between the workpiece and the carriage, and the cutting head being transversely mobile along the carriage;
determining a cut path along the workpiece based on the positioning angle; and
following the cut path with the cutting head by applying longitudinal relative motion between the workpiece and the carriage while transversely moving the cutting head along the carriage.

10. The method of claim 9, wherein the workpiece is a rectangular panel, the cut path is parallel with at least one minor side of the workpiece, and the cut path defines a non-zero angle with respect to both the transverse and longitudinal directions.

11. A method of cutting a workpiece, the method comprising:
determining a positioning angle defined between the workpiece and a cutting assembly, the cutting assembly comprising a carriage supporting a first and second cutting heads, the carriage being longitudinally mobile, the first and second cutting heads being independently transversely mobile along the carriage;
determining a first and second cut paths along the workpiece based on the positioning angle;
following, with the first cutting head, the first cut path by longitudinally moving the carriage while transversely moving the first cutting head along the carriage such that the first cutting head experiences simultaneous longitudinal and transverse motion; and

following, with the second cutting head, the second cut path by longitudinally moving the carriage while transversely moving the second cutting head along the carriage such that the second cutting head experiences simultaneous longitudinal and transverse motion,

wherein the first cutting head begins following the first cut path before the second cutting head begins following the second cut path, the second cutting head begins following the second cut path before the first cutting head completes the first cut path, and the first cutting head completes the first cut path before the second cutting head completes the second cut path.

12. The method of claim 11, wherein the first and second cut paths have equal lengths.

13. The method of claim 11 comprising:

switching the first cutting head from a disengaged mode to an engaged mode when the first cutting head begins the first cut path, and switching the first cutting head from the engaged mode to the disengaged mode when the first cutting head completes the first cut path;

switching the second cutting head from a disengaged mode to an engaged mode when the second cutting head begins the second cut path, and switching the second cutting head from the engaged mode to the disengaged mode when the second cutting head completes the second cut path;

wherein the first and second cutting heads are capable of cutting the workpiece while in the engaged modes but are incapable of cutting the workpiece while in the disengaged modes;

the first cutting head switching to the engaged mode prior to the second cutting head switching to the engaged mode;

the second cutting head remaining in the engaged mode after the first cutting head returns to the disengaged mode.

14. A system for cutting a workpiece, the system comprising:

a cutting assembly comprising a carriage supporting a cutting head, the carriage configured for longitudinal movement, the cutting head configured for transverse movement along the carriage;

a processing system comprising one or more processors configured to:

determine a positioning angle defined between the workpiece and the cutting assembly;

determine a cut path along the workpiece based on the positioning angle; and

cause the cutting head to follow the cut path by causing the carriage to move longitudinally while causing the cutting head to move transversely along the carriage such that the cutting head experiences simultaneous longitudinal and transverse motion.

15. The system of claim 14, wherein the workpiece is a rectangular panel and the one or more processors are configured to:

determine the cut path such that (i) the cut path is parallel with at least one minor side of the workpiece, (ii) the cut path is perpendicular to at least one major side of the workpiece, and (iii) the cut path defines a non-zero angle with respect to both the transverse and longitudinal directions.

16. The system of claim 14, wherein the one or more processors are configured to:

cause the carriage to move longitudinally, but not transversely, while the cutting head follows the cut path.

17. The system of claim 14 wherein the processing system is further configured to:

determine a length of a side of the workpiece;

determine a distance D based on the determined length and the determined positioning angle; and

cause the cutting head to move transversely the distance D along the carriage while the cutting head follows the cut path.

18. The system of claim 14 wherein the one or more processors are configured to:

determine the cut path such that the cut path is a line segment extending from a first side of the workpiece to an opposing second side of the workpiece such that by following the cut path, the cutting head severs the workpiece into discrete and detached portions.

19. The system of claim 14 wherein the one or more processors are configured to:

determine the cut path such that the cut path defines a cut angle with respect to the longitudinal axis, a magnitude of the cut angle equaling a magnitude of the positioning angle.

20. The system of claim 14 wherein the one or more processors are configured to:

determine the cut path based on a trigonometric function of the positioning angle.

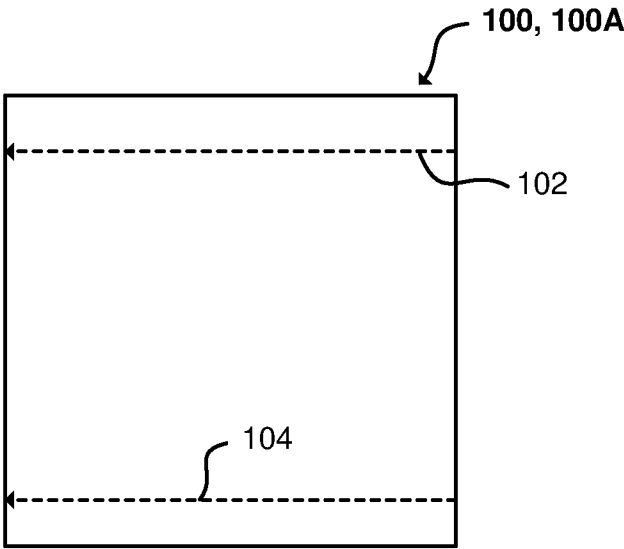


FIG. 1A

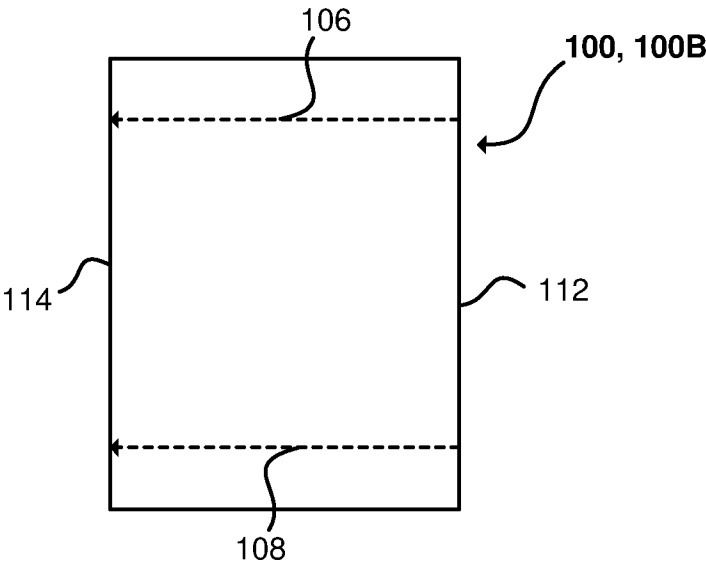


FIG. 1B

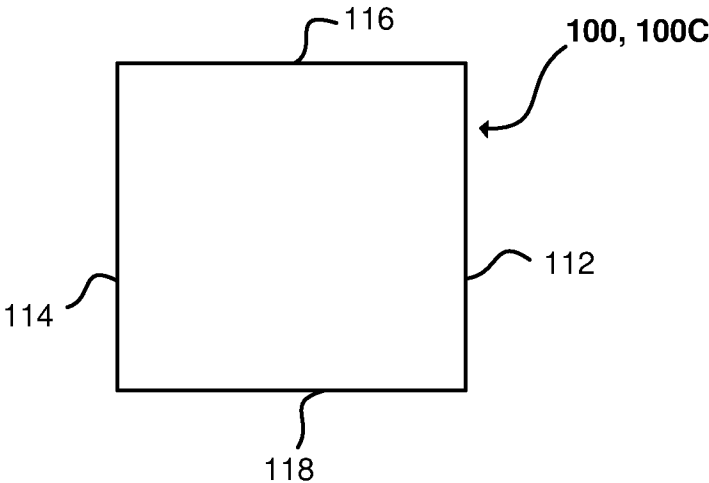
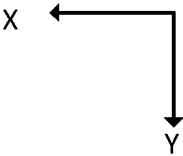


FIG. 1C



2/9

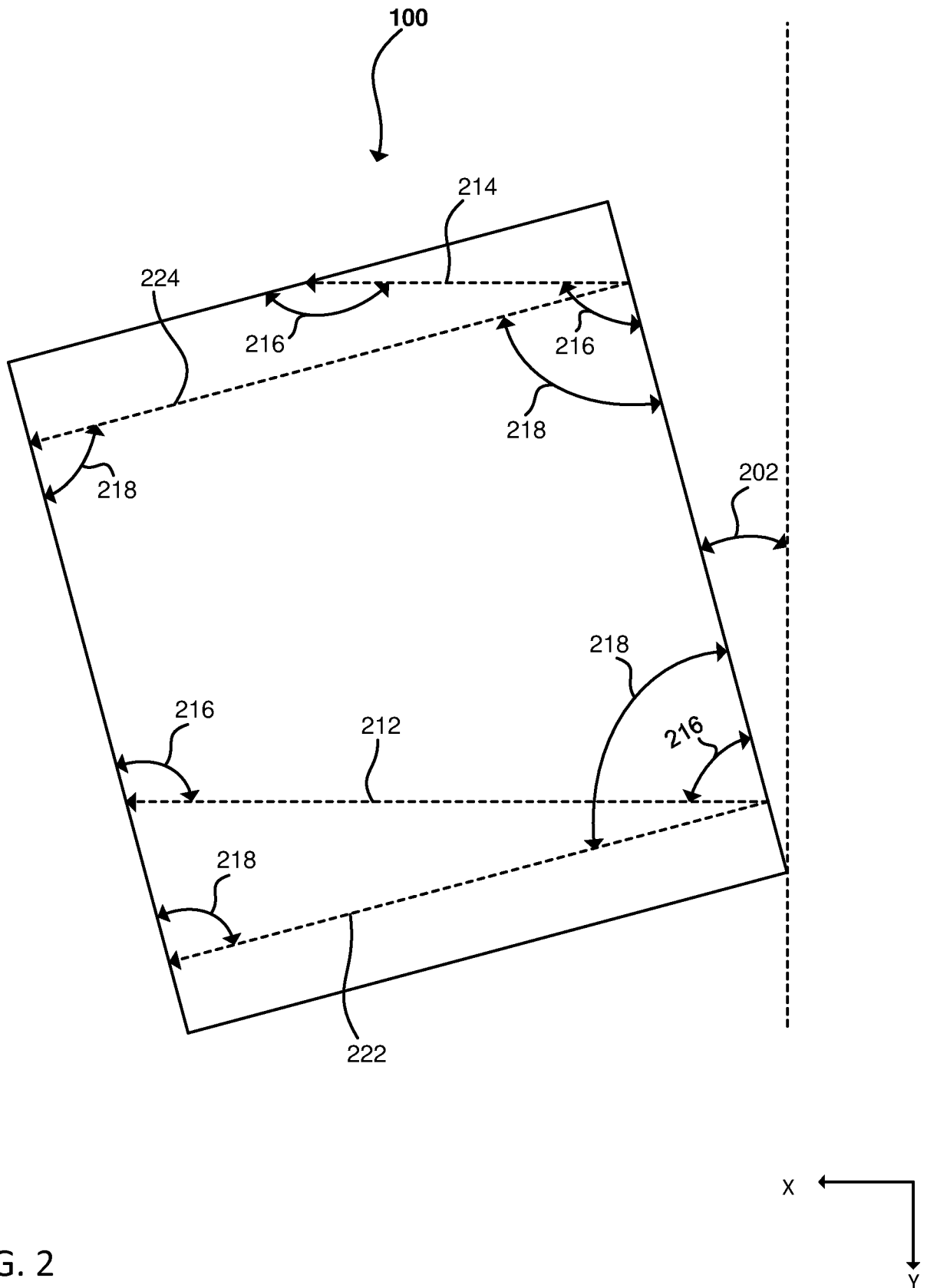
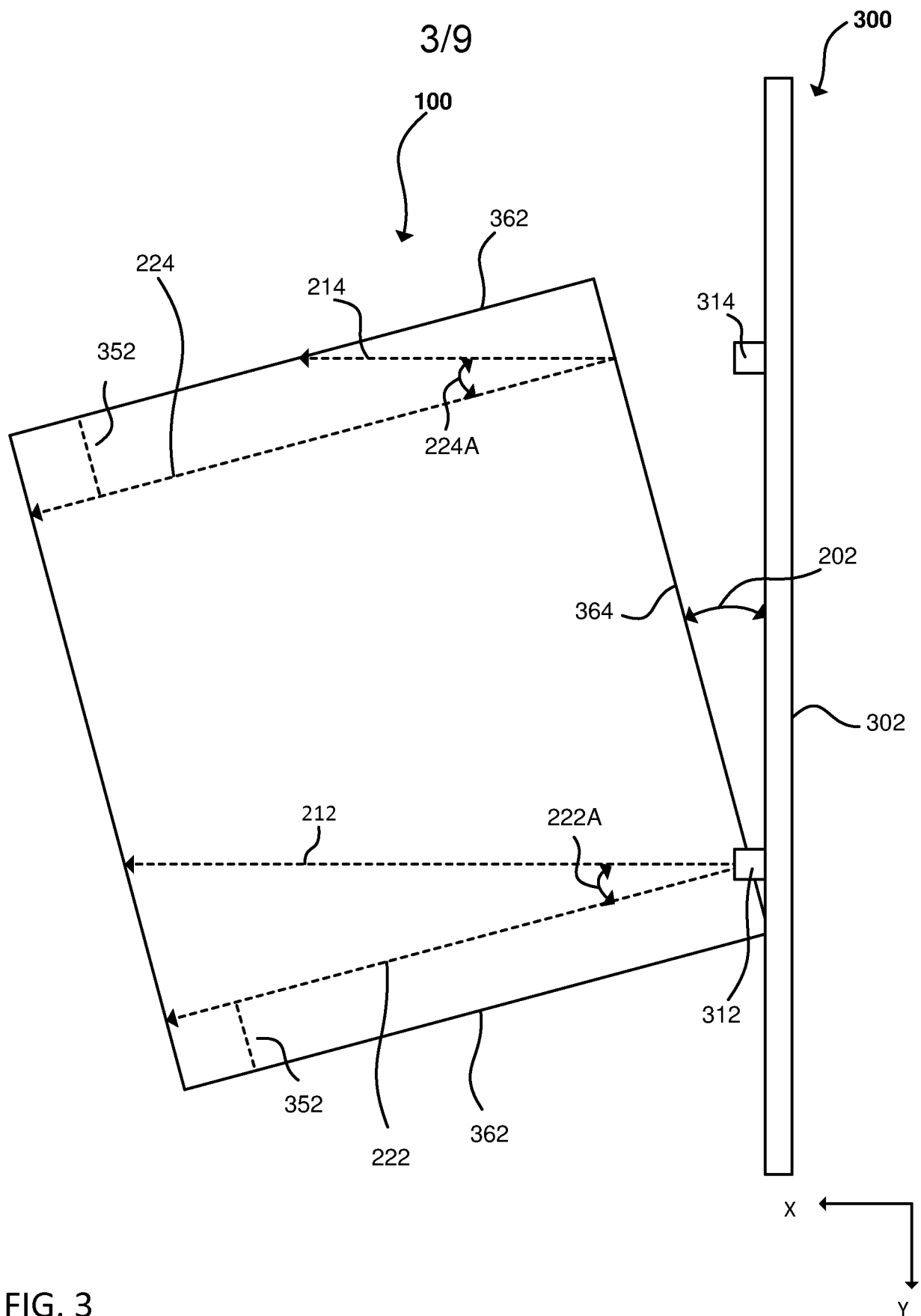


FIG. 2



4/9

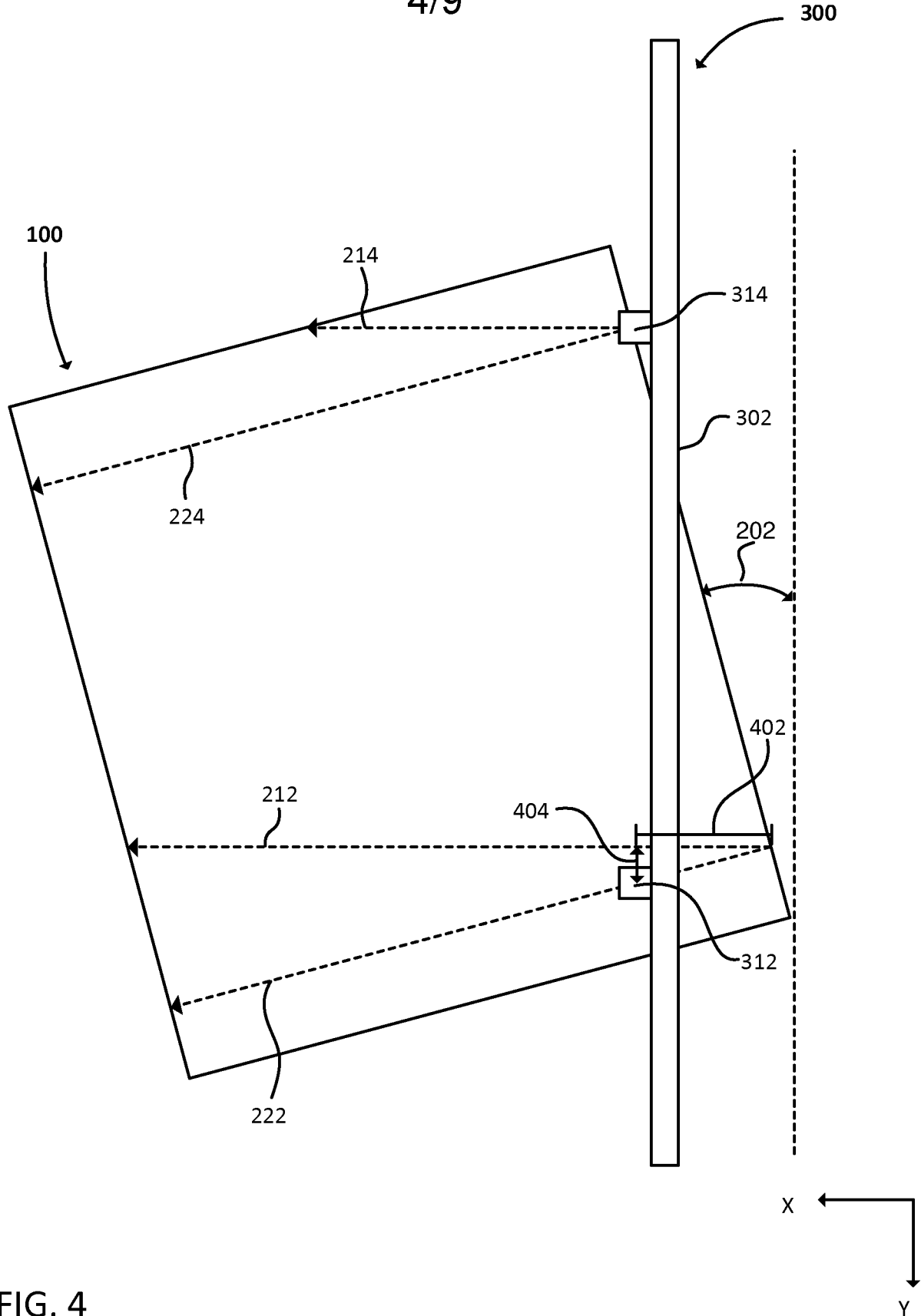
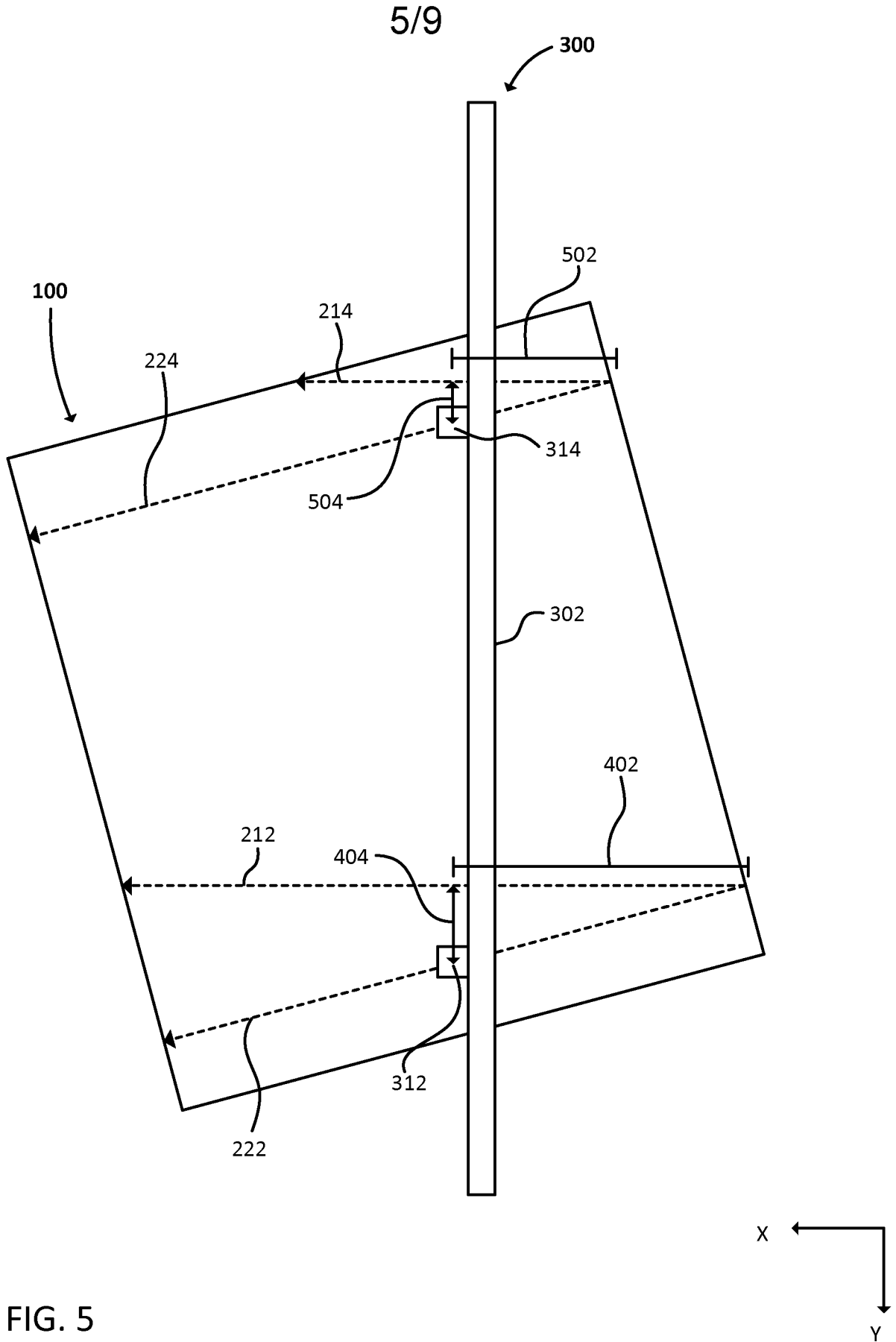


FIG. 4



6/9

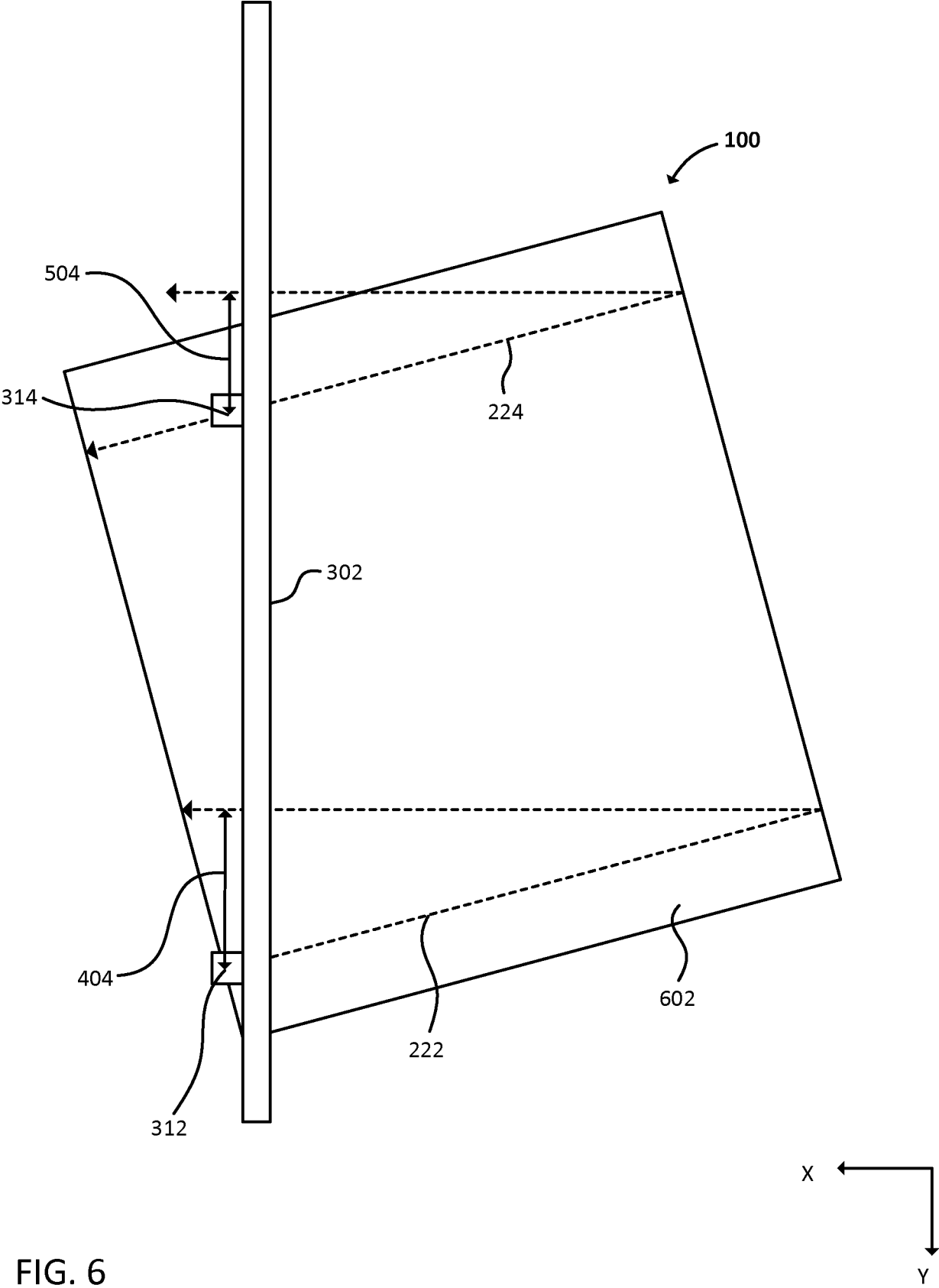


FIG. 6

7/9

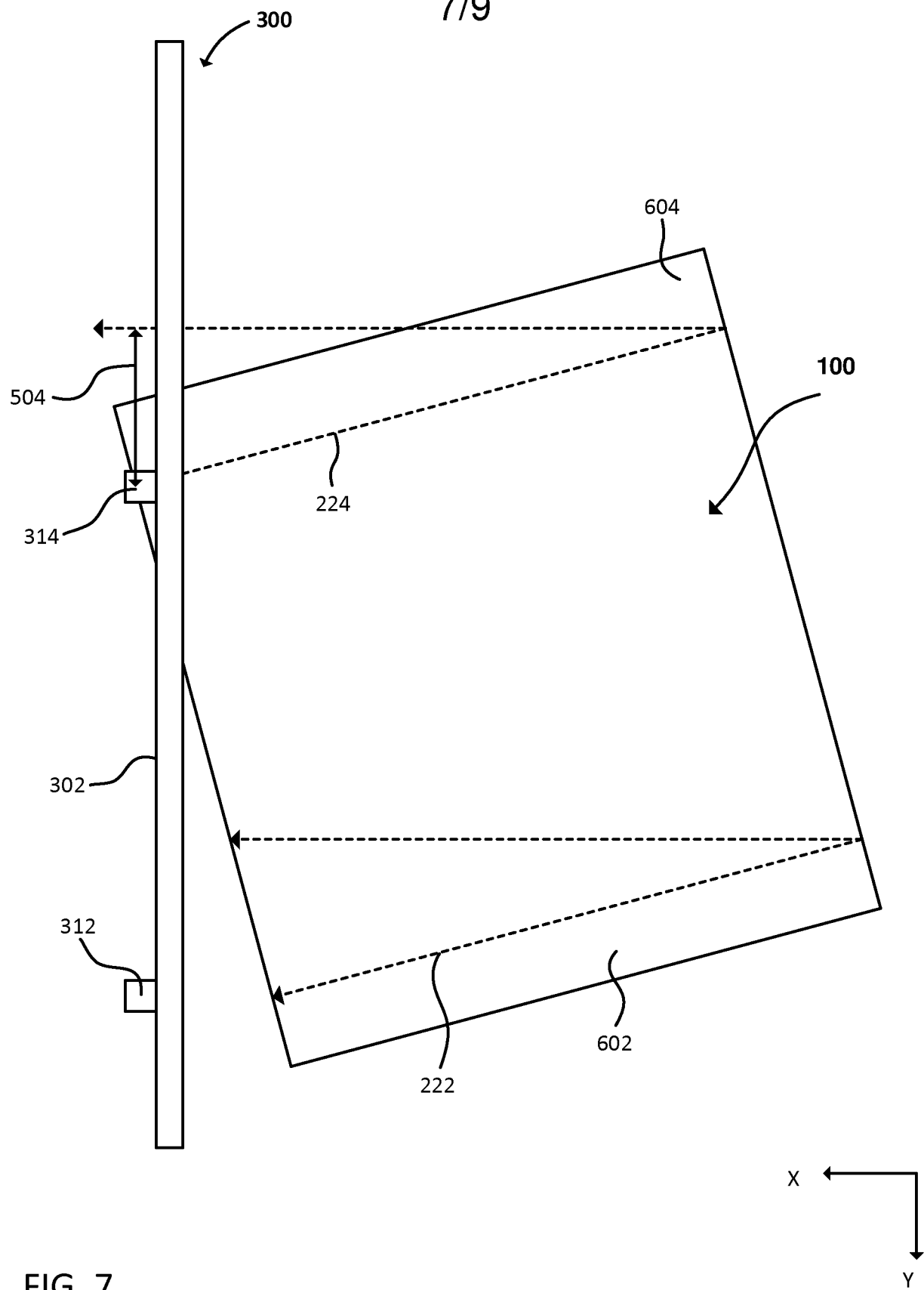


FIG. 7

8/9

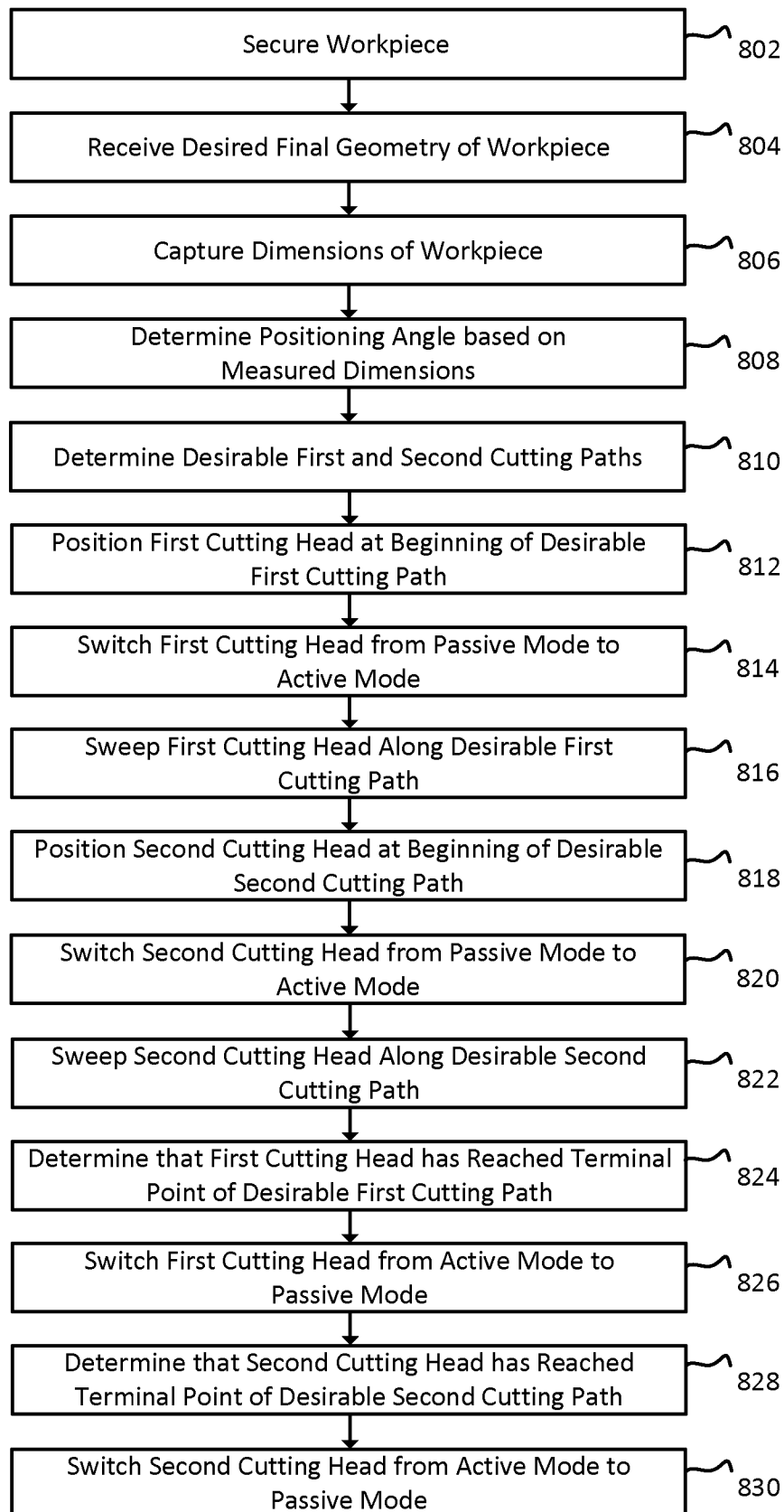


FIG. 8

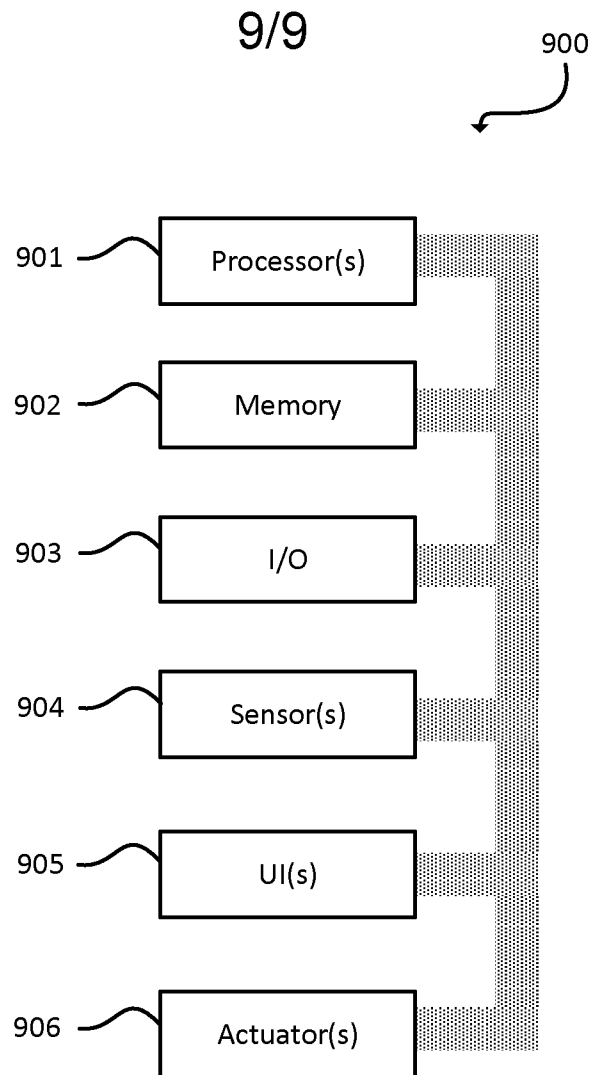


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2020/031552**A. CLASSIFICATION OF SUBJECT MATTER****B26D 5/02(2006.01)i, B26D 5/20(2006.01)i, B23D 15/06(2006.01)i, B26D 1/04(2006.01)i, B23D 33/12(2006.01)i**

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)

B26D 5/02; B23K 26/10; B26D 005/00; B26D 5/00; B26D 5/24; B65H 31/10; B65H 31/20; D06H 7/00; B26D 5/20; B23D 15/06; B26D 1/04; B23D 33/12

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: workpiece, positioning angle, cutting assembly, carriage, cutting head, cut path

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4133234 A (GERBER, HEINZ J.) 09 January 1979 column 4, lines 28-56; claim 1; and figures 1, 15	1-10, 14-20
A		11-13
Y	US 2005-0204887 A1 (FRIES, ROLAND) 22 September 2005 paragraphs [0002]-[0028]; and figure 3	1-10, 14-20
Y	WO 2013-062934 A2 (LASERMAX ROLL SYSTEMS, INC. et al.) 02 May 2013 claim 1; and figure 8	8
A	JP 2018-510782 A (TRUMPF WERKZEUGMASCHINEN GMBH & CO. KG) 19 April 2018 claims 1-15; and figures 1a-1b, 2, 4a-4b, 5	1-20
A	KR 10-1407473 B1 (BAE, OK IM) 17 June 2014 paragraphs [0010]-[0034]; and figures 1a-1b, 2-4	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

14 August 2020 (14.08.2020)

Date of mailing of the international search report

20 August 2020 (20.08.2020)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea



Facsimile No. +82-42-481-8578

Authorized officer

BAHNG SEUNG HOON

Telephone No. +82-42-481-5560



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2020/031552

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4133234 A	09/01/1979	CA 1093193 A CA 1103786 A CA 1179422 A JP 53-132878 A JP 56-021558 B2 US 4178820 A	06/01/1981 23/06/1981 11/12/1984 20/11/1978 20/05/1981 18/12/1979
US 2005-0204887 A1	22/09/2005	CA 2500878 A1 US 2005-0204888 A1	16/09/2005 22/09/2005
WO 2013-062934 A2	02/05/2013	EP 2470336 A1 EP 2470336 B1 EP 2771266 A2 EP 2771266 B1 EP 2771266 B8 EP 3153440 A1 EP 3339227 A1 US 2011-0049781 A1 US 2012-0098184 A1 US 2012-0193860 A1 US 8167293 B2 US 8485512 B2 US 8882099 B2 WO 2011-031486 A1 WO 2013-062934 A3	04/07/2012 14/08/2013 03/09/2014 20/12/2017 15/05/2019 12/04/2017 27/06/2018 03/03/2011 26/04/2012 02/08/2012 01/05/2012 16/07/2013 11/11/2014 17/03/2011 13/06/2013
JP 2018-510782 A	19/04/2018	CN 107427952 A CN 107427952 B DE 102015204562 A1 EP 3268162 A1 EP 3268162 B1 JP 6509365 B2 KR 10-2017-0128511 A KR 10-2100023 B1 PL 3268162 T3 US 10722978 B2 US 2018-0001421 A1 WO 2016-146358 A1	01/12/2017 12/11/2019 15/09/2016 17/01/2018 07/08/2019 08/05/2019 22/11/2017 10/04/2020 31/03/2020 28/07/2020 04/01/2018 22/09/2016
KR 10-1407473 B1	17/06/2014	None	