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Crosby et al.

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(54) **SPINDLE FOR A RECREATIONAL VEHICLE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **18/955,842**

(22) Filed: **Nov. 21, 2024**

(65) **Prior Publication Data**

US 2025/0083486 A1 Mar. 13, 2025

Related U.S. Application Data

(63) Continuation of application No. 17/988,304, filed on Nov. 16, 2022, now Pat. No. 12,179,545.

(60) Provisional application No. 63/404,841, filed on Sep. 8, 2022, provisional application No. 63/310,276, filed on Feb. 15, 2022.

(51) **Int. Cl.**
B60G 7/00 (2006.01)
B60G 7/02 (2006.01)

(52) **U.S. Cl.**
CPC ***B60G 7/001*** (2013.01); ***B60G 7/008*** (2013.01); ***B60G 7/02*** (2013.01)

(58) **Field of Classification Search**
CPC B60G 7/001; B60G 7/008; B60G 7/02; B62D 17/00; B62M 27/02
See application file for complete search history.

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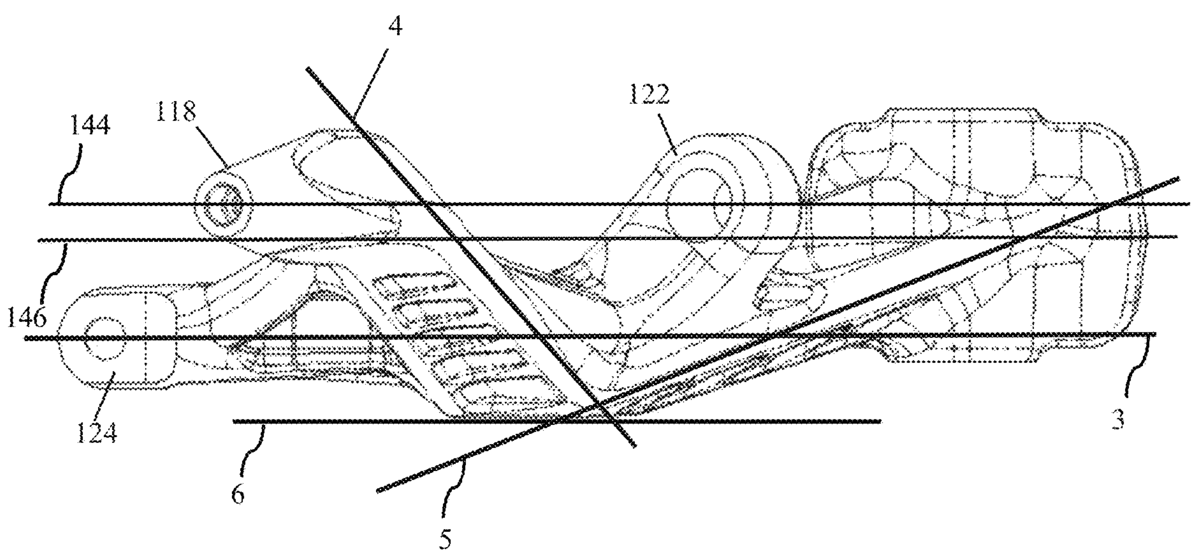
(57) **ABSTRACT**

Embodiments of the present disclosure describe a recreational vehicle spindle for use with a snowmobile, a snow bike, all-terrain vehicle (ATV), or a side by side vehicle (SxS or UTV). The spindle includes a body with one or more mounts for securing a suspension component and a ground engaging member thereto. The body of the spindle may include one or more of a window, a recess, a leading edge, a triangular cross-sectional shape, an integrated steering stop, and an outboard side that includes a flat surface.

19 Claims, 37 Drawing Sheets



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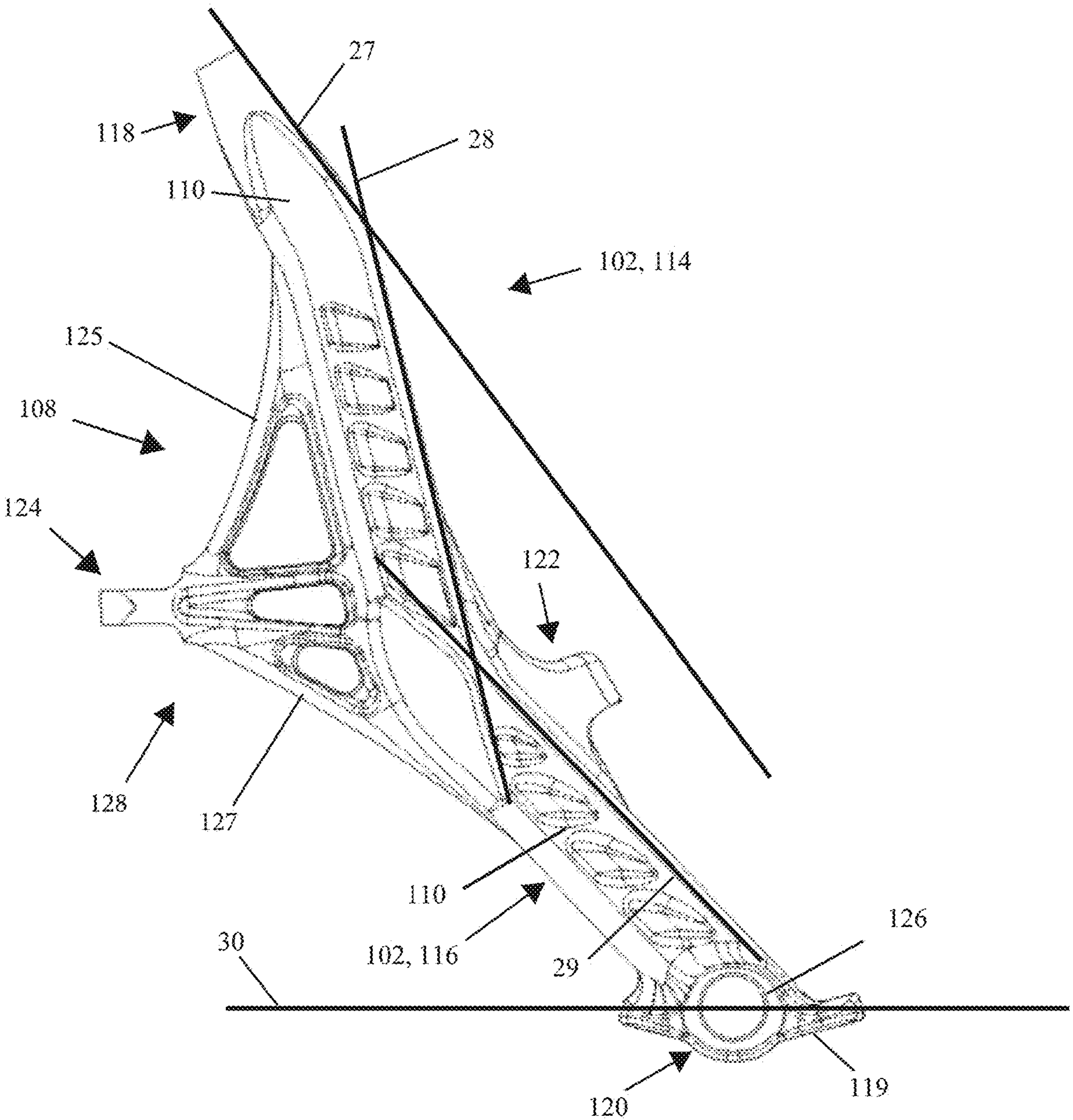
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FIG. 1A

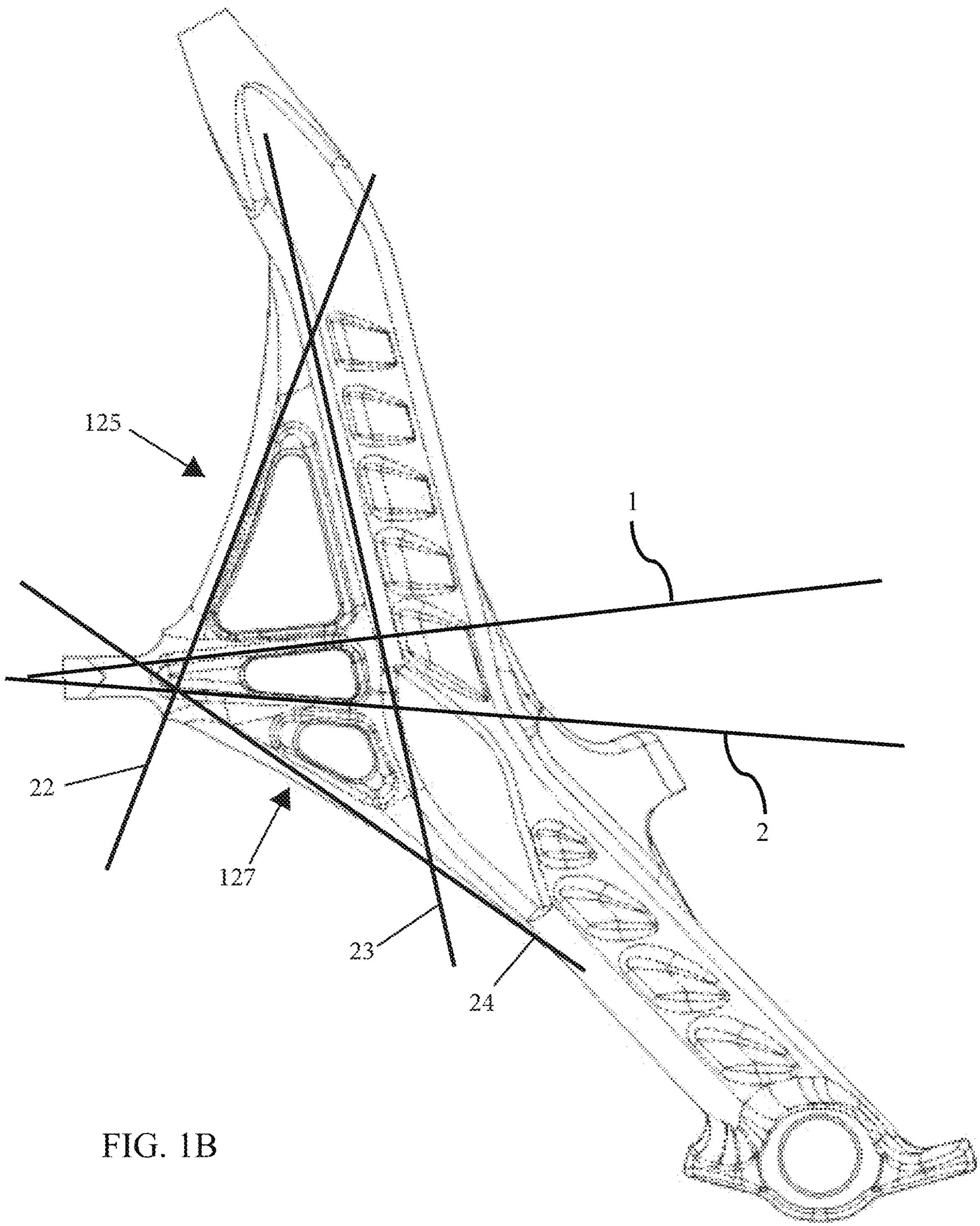

FIG. 1B

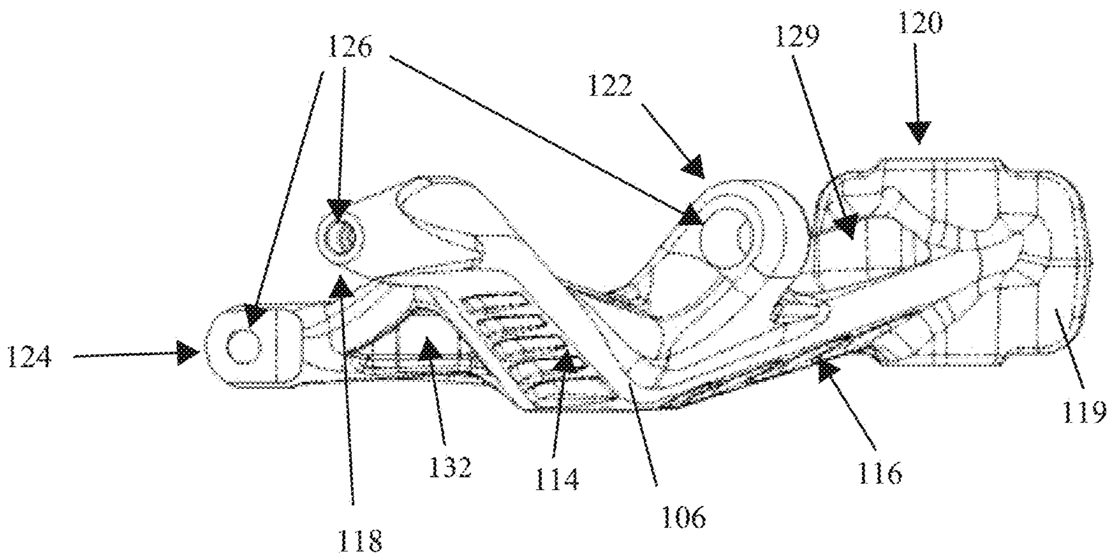

FIG. 2A

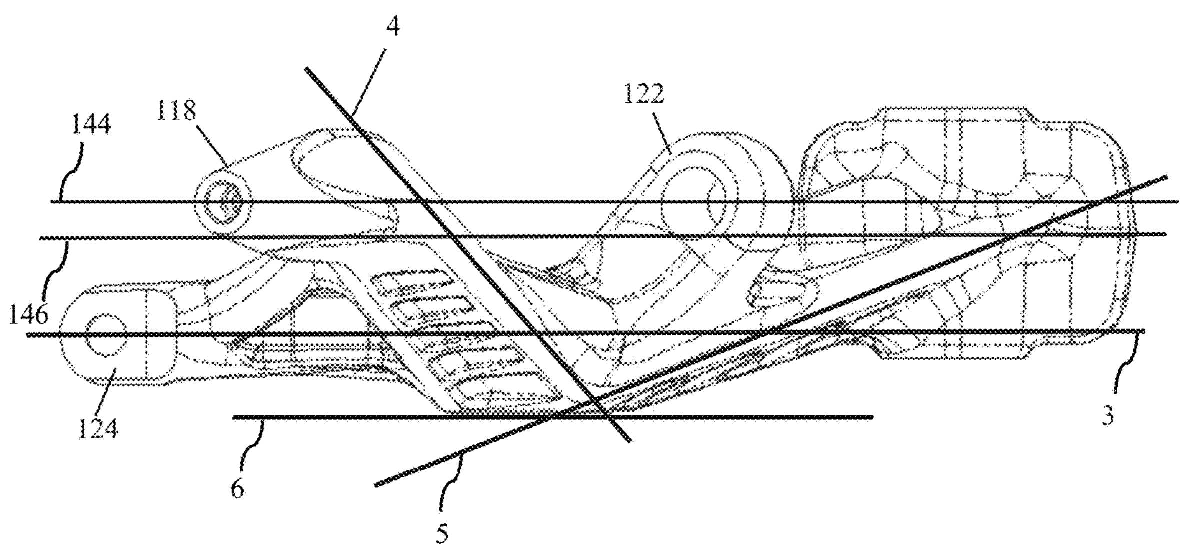

FIG. 2B

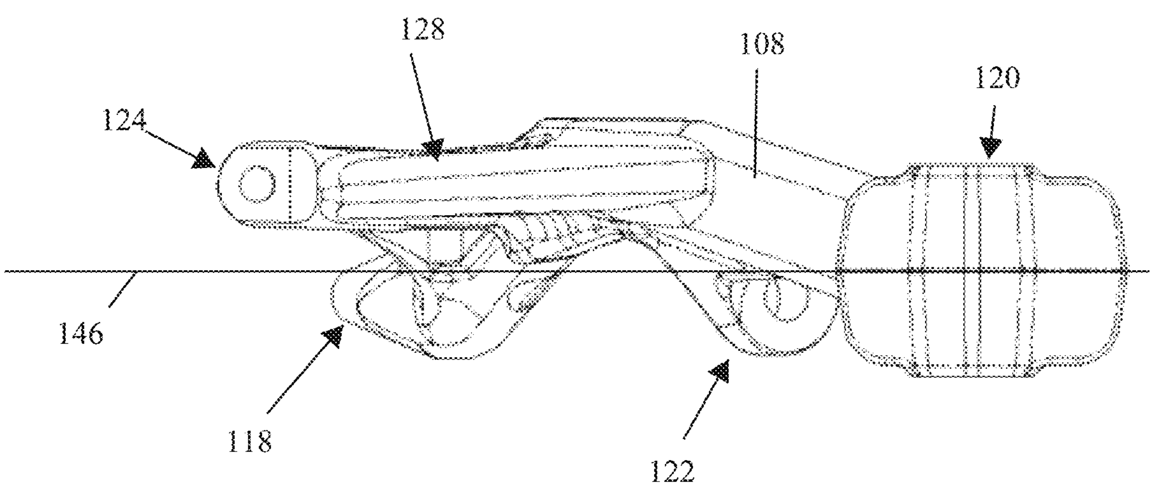

FIG. 3

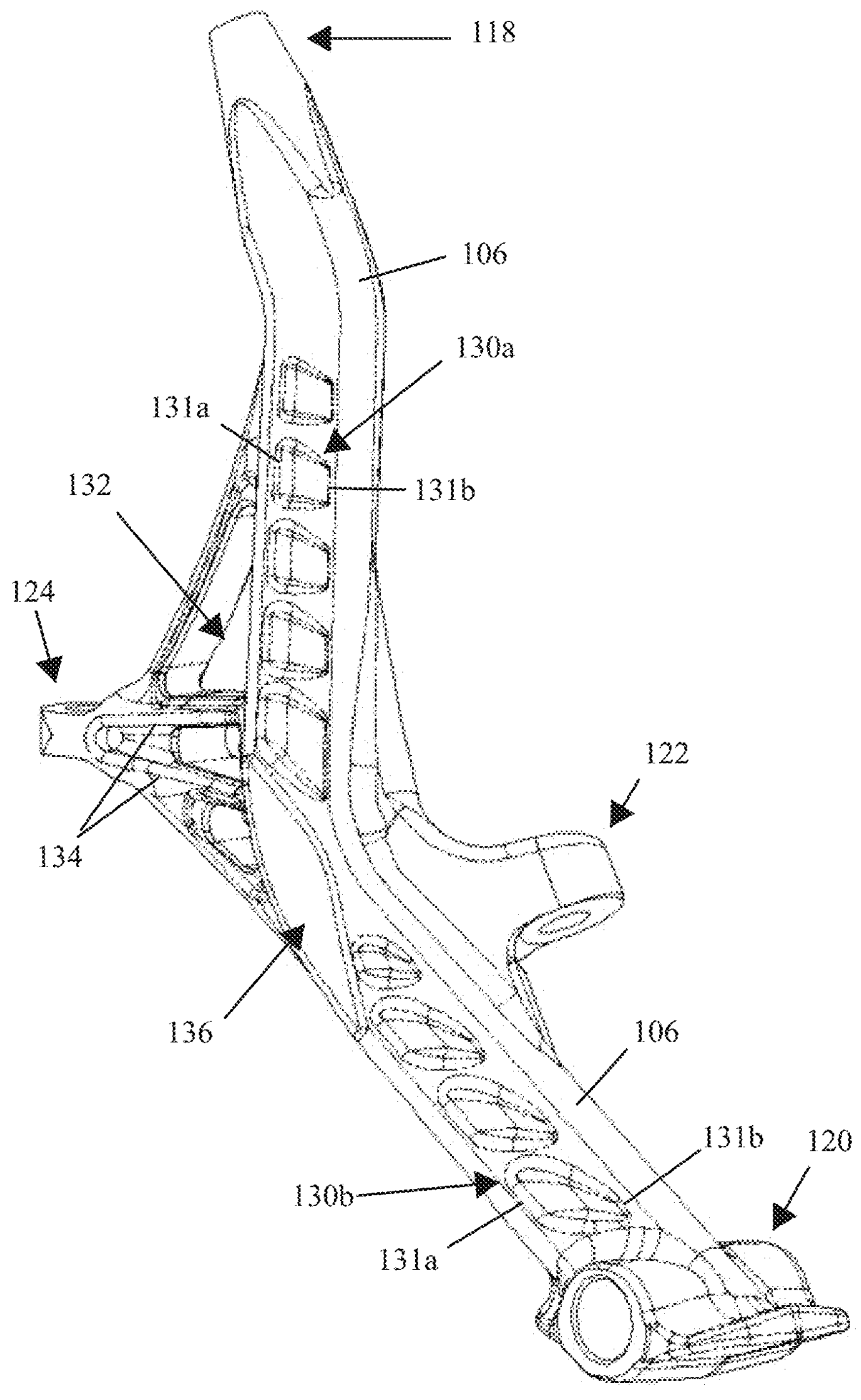
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FIG. 4A

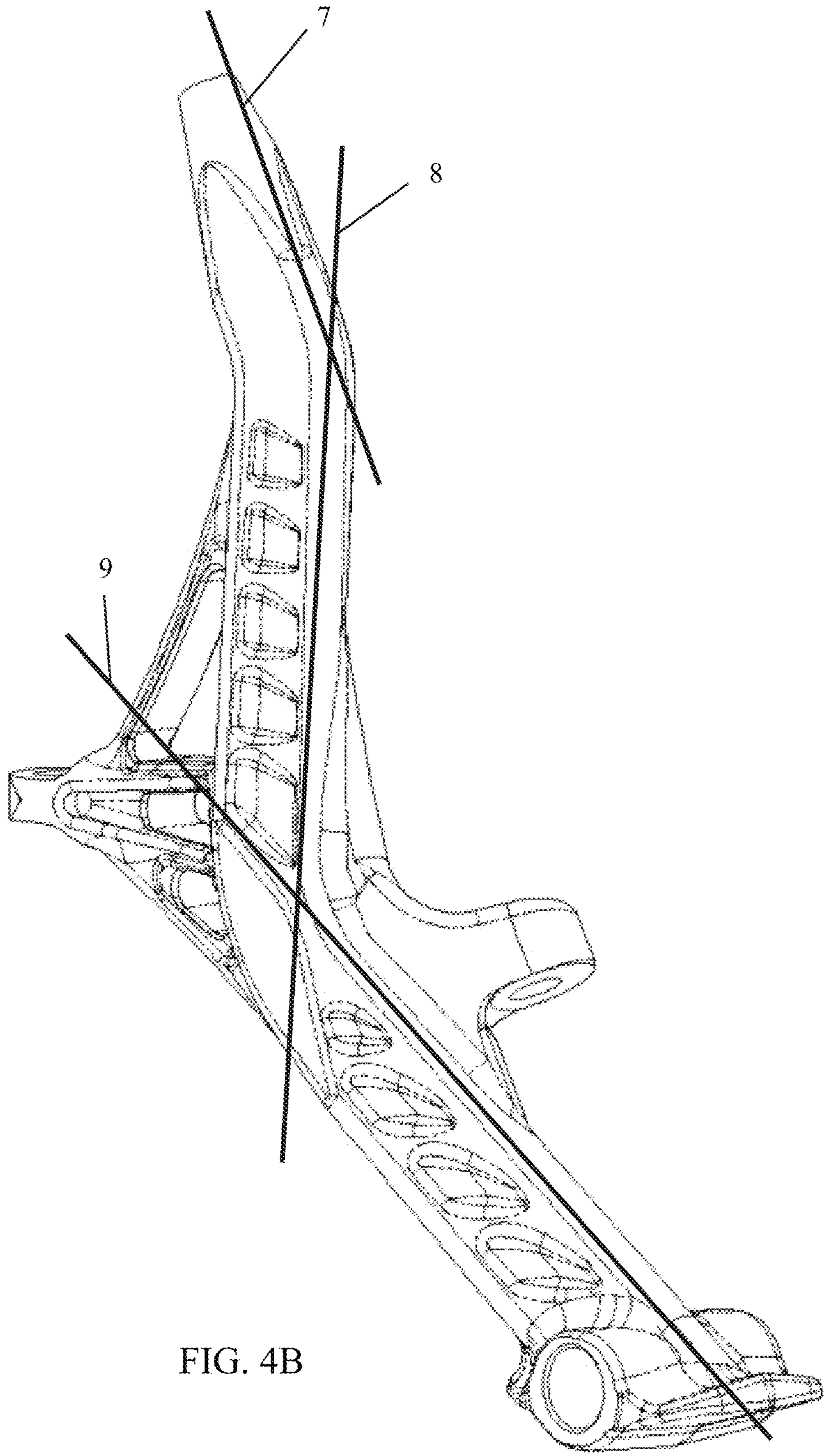

FIG. 4B

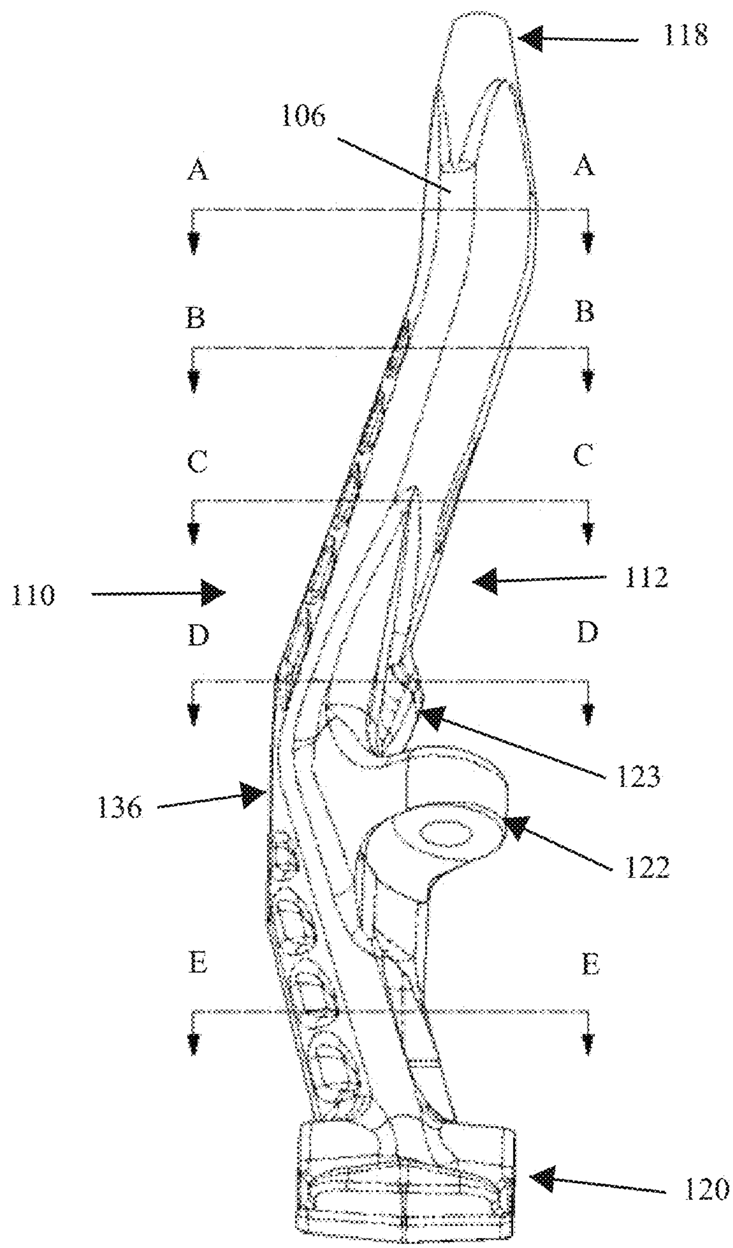

FIG. 5

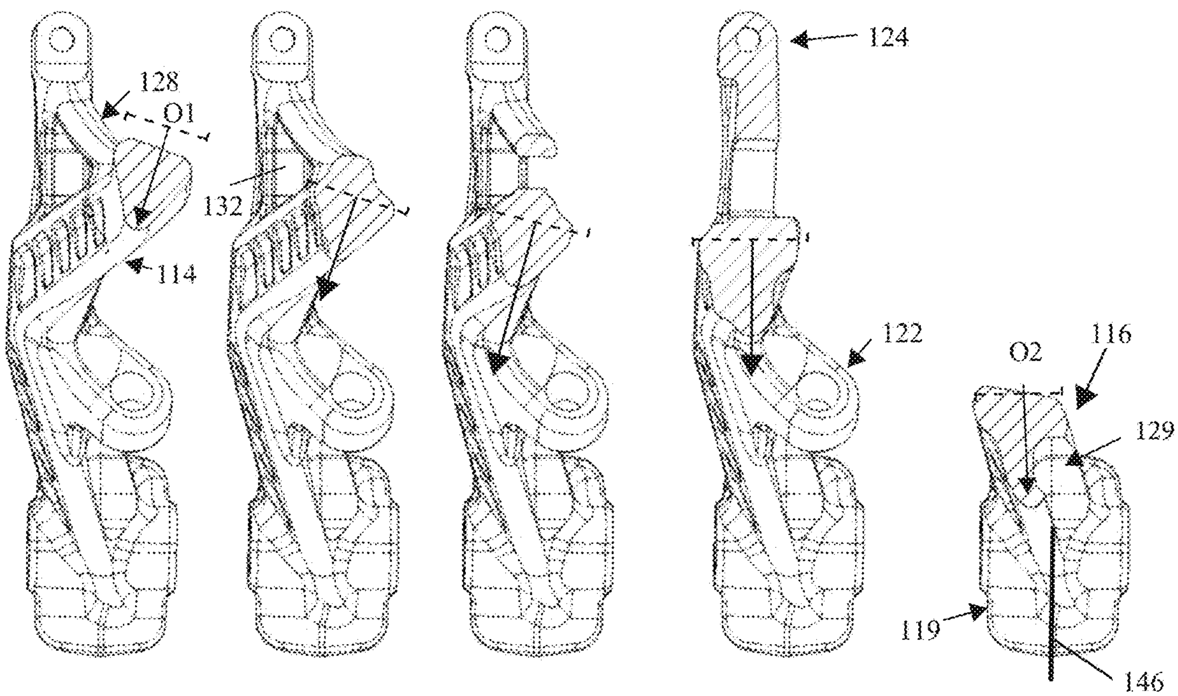

FIG. 5A FIG. 5B FIG. 5C FIG. 5D FIG. 5E

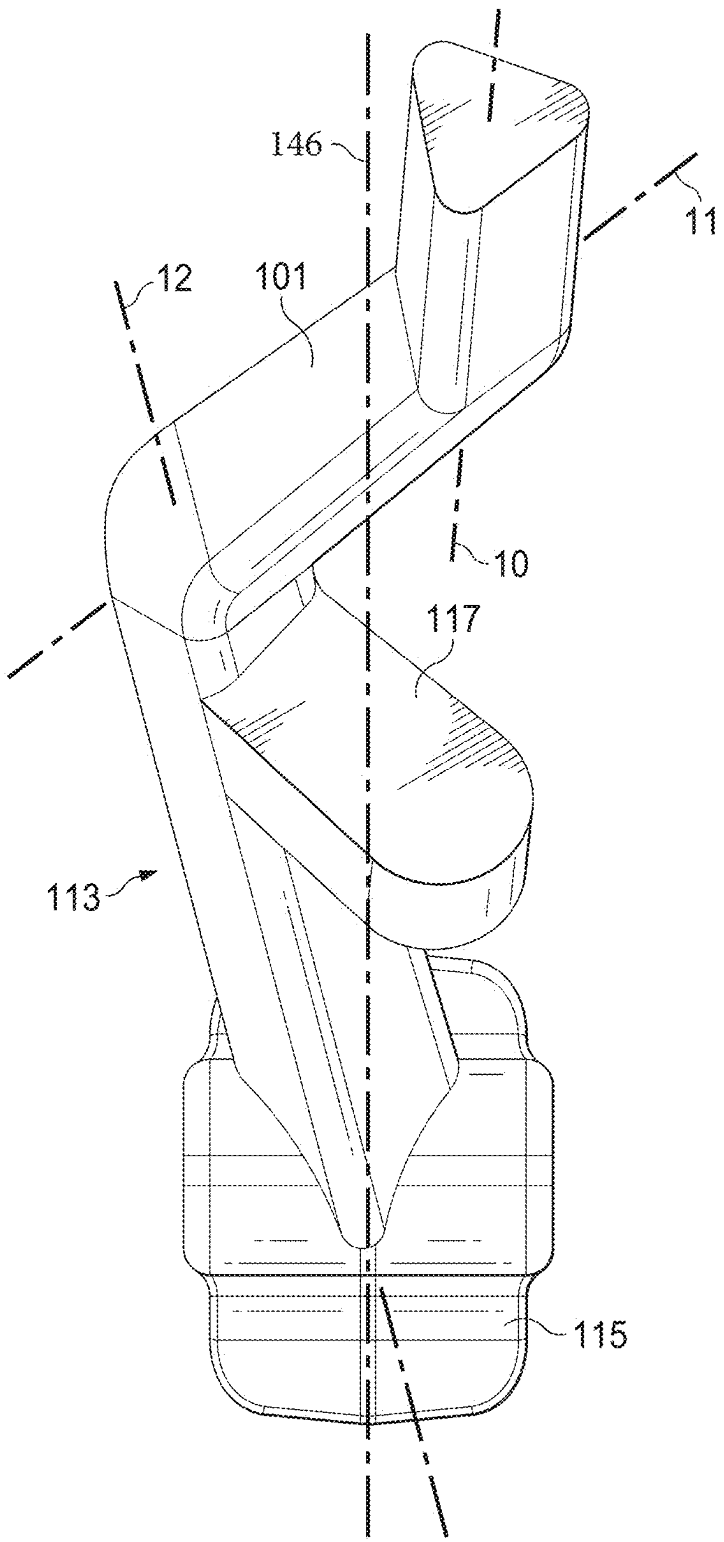

FIG. 5F

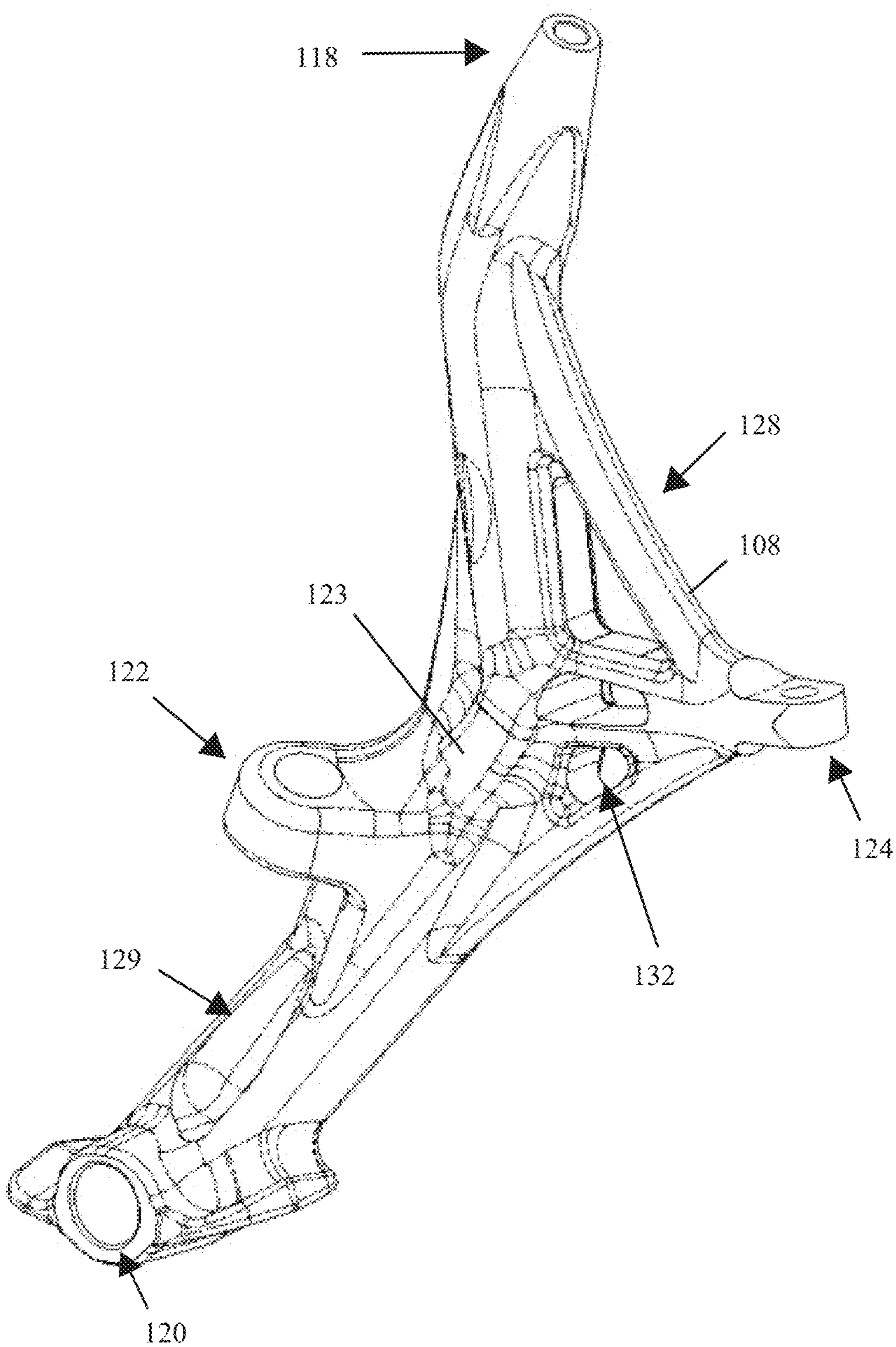

FIG. 6

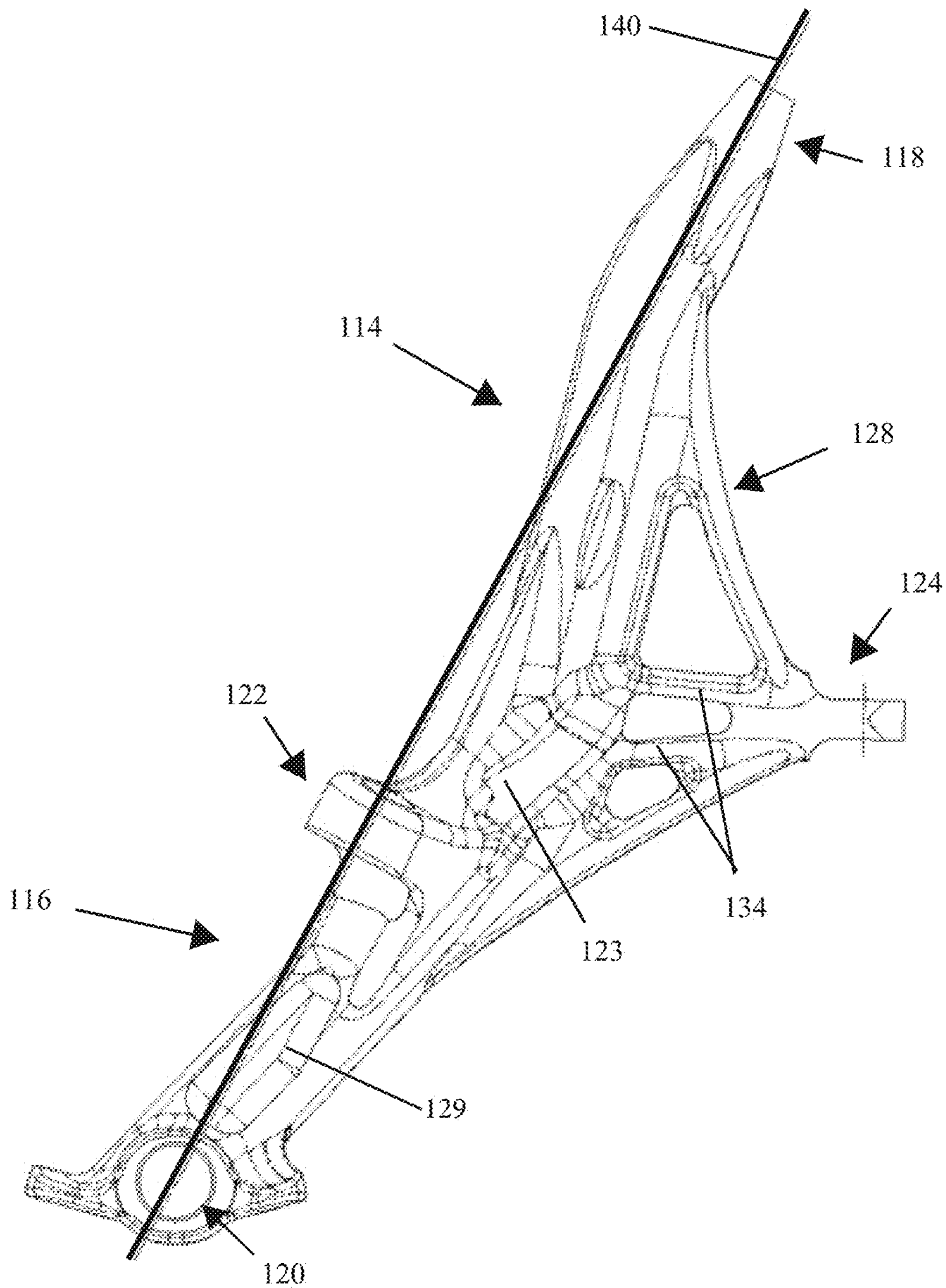

FIG. 7

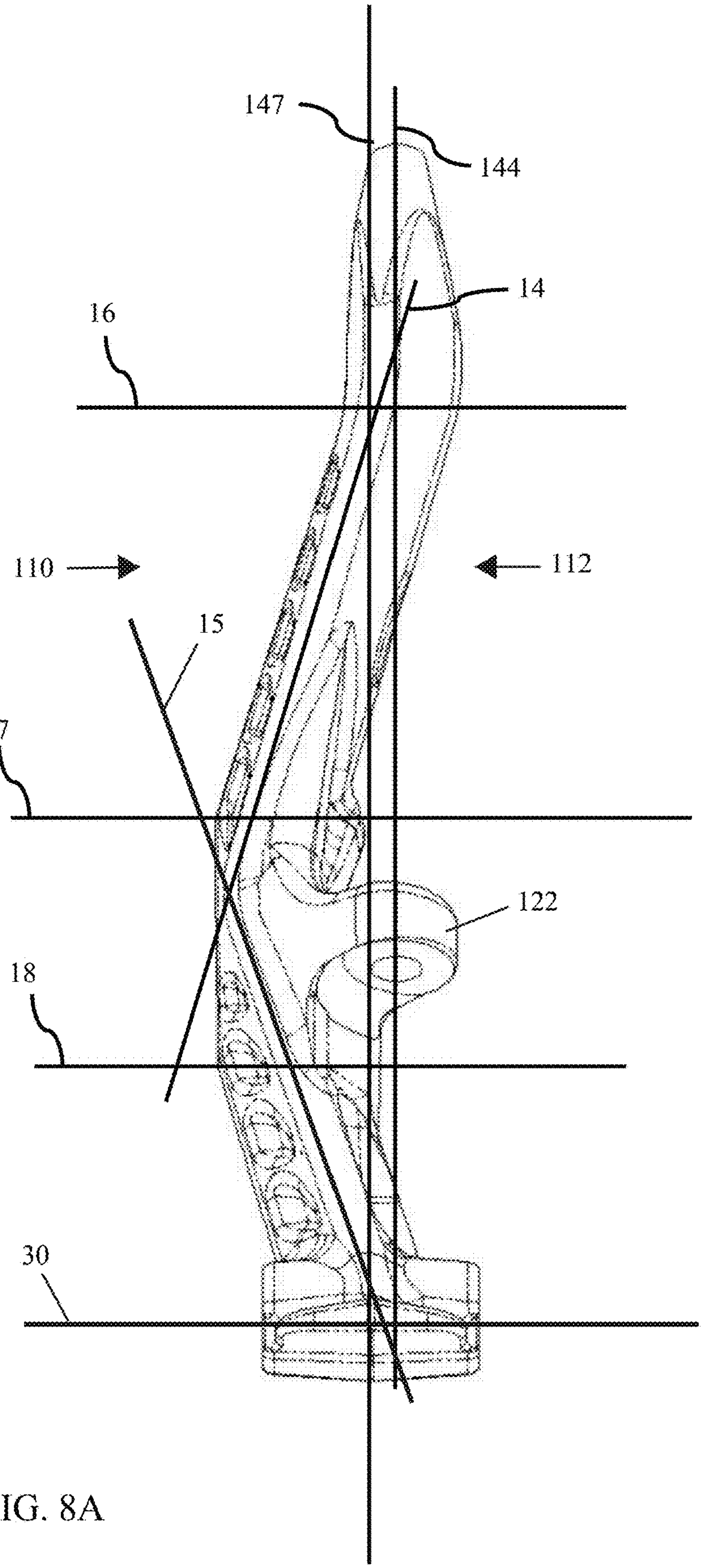

FIG. 8A

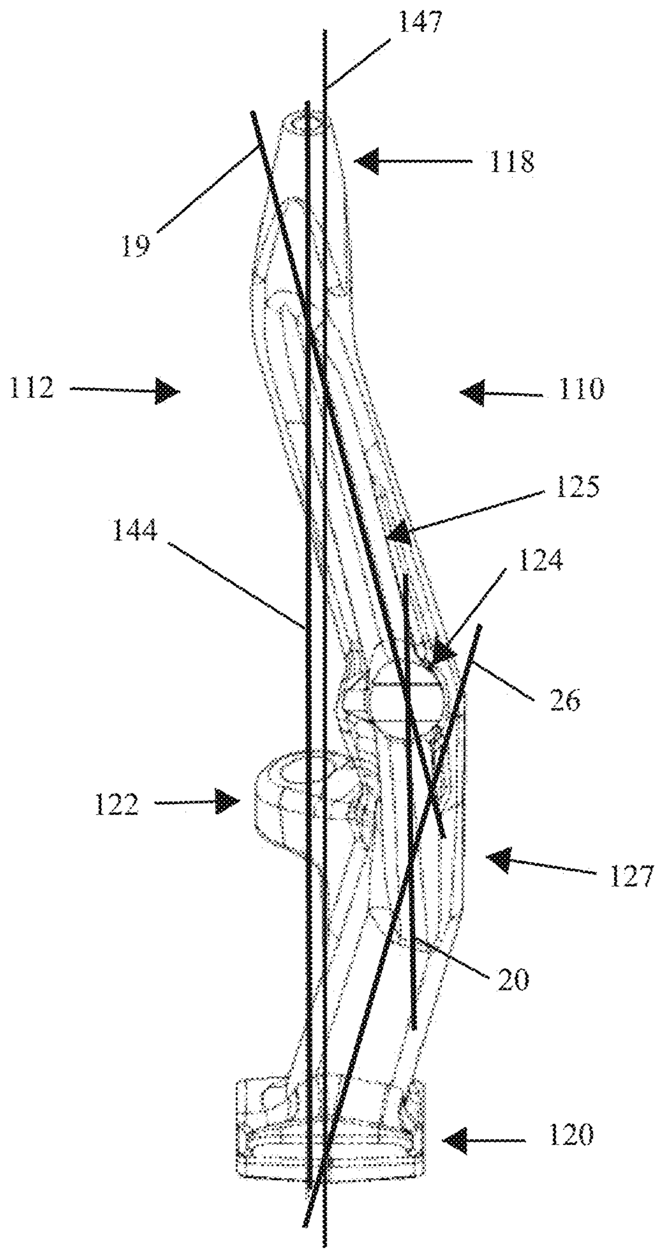

FIG. 8B

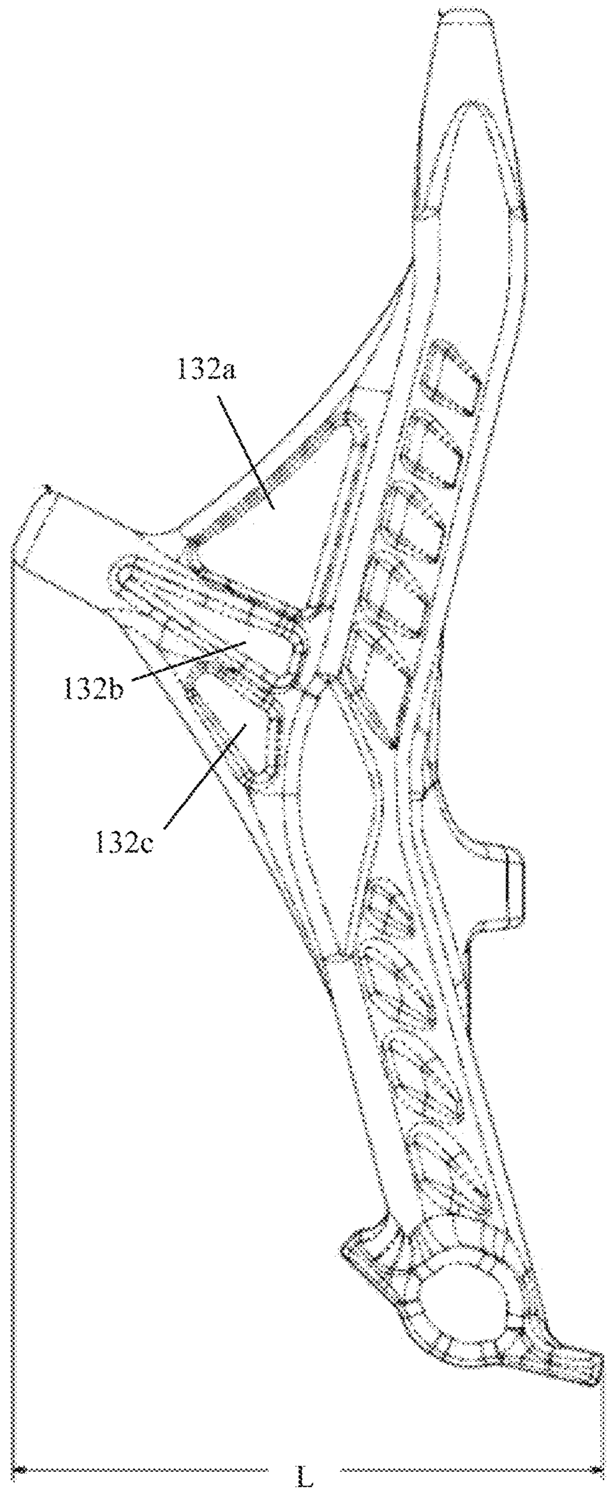

FIG. 9A

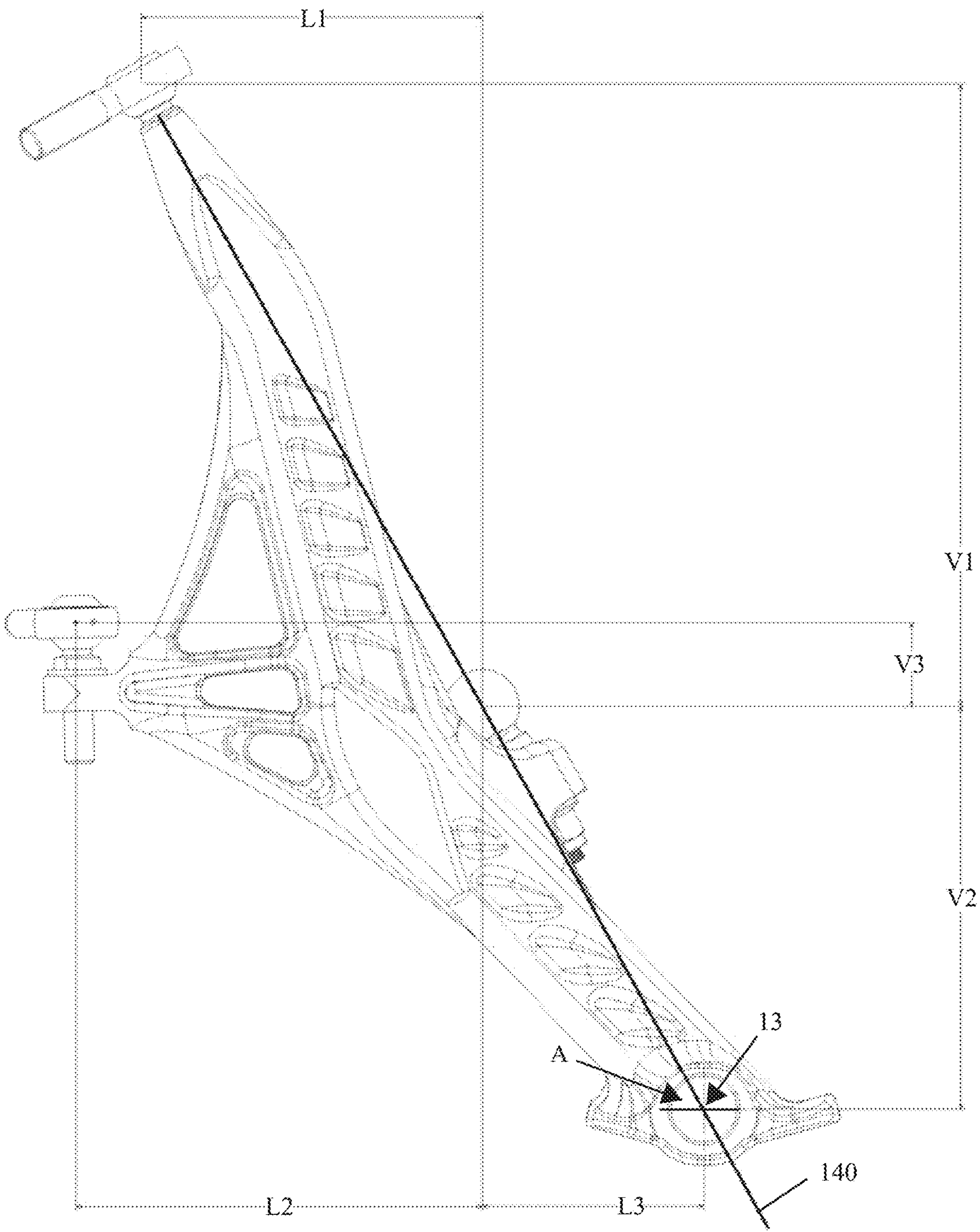

FIG. 9B

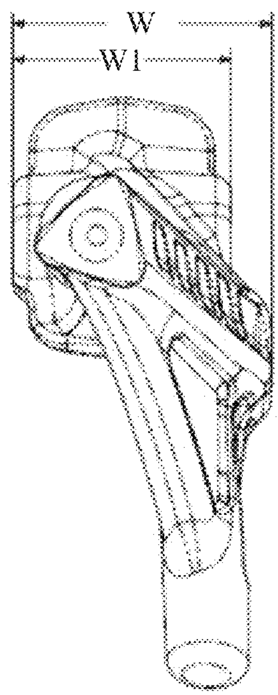

FIG. 9C

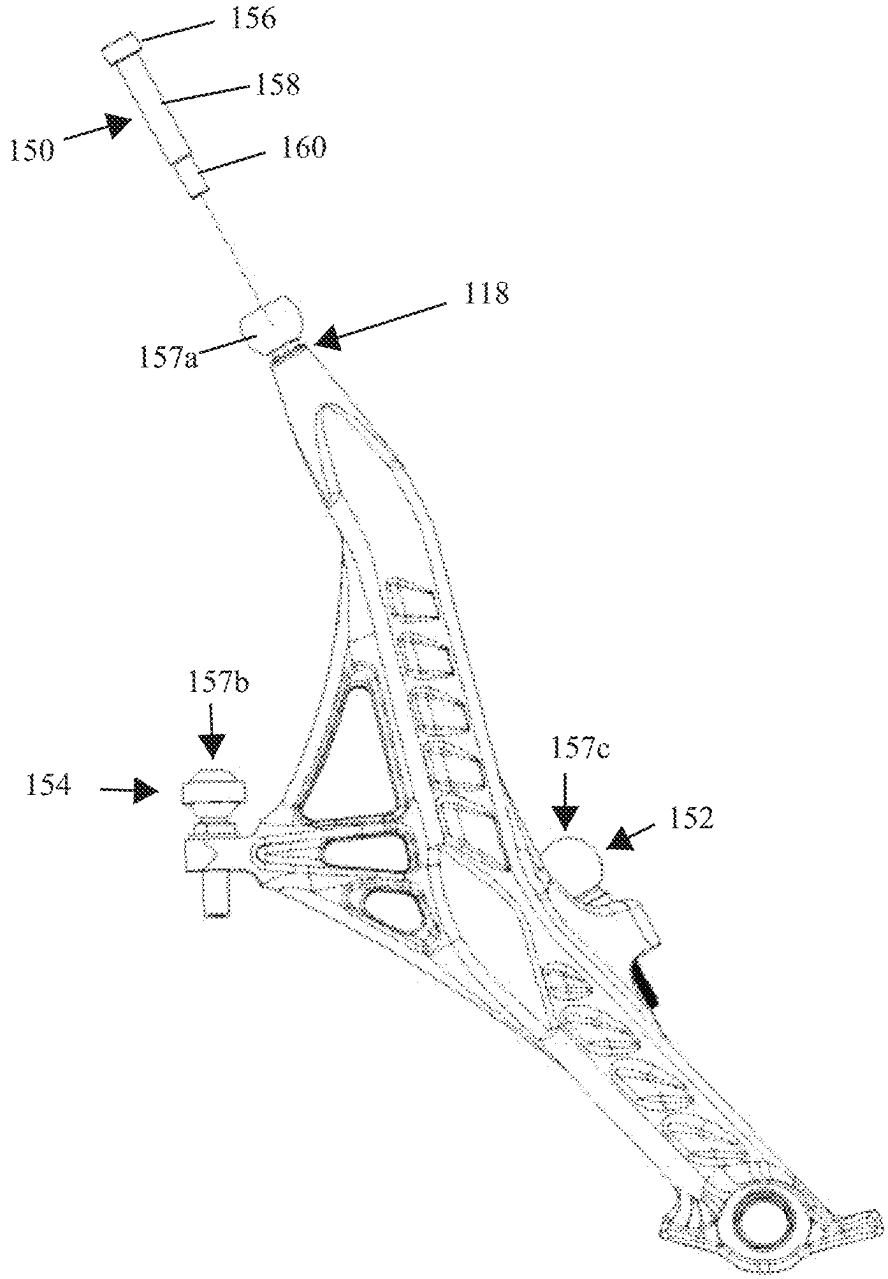

FIG. 10A

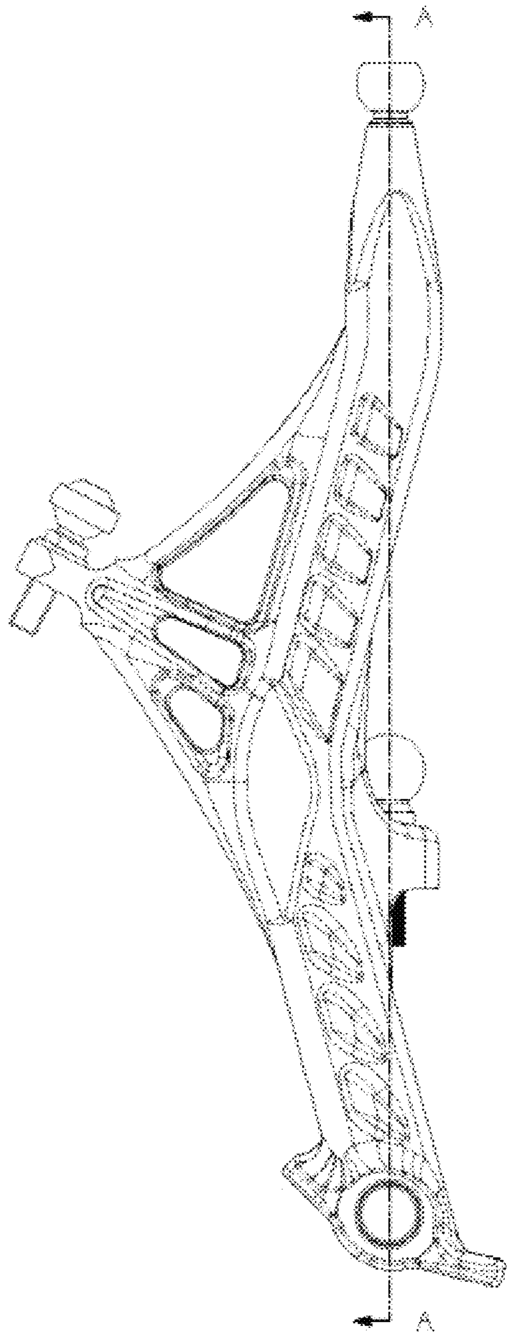

FIG. 10B

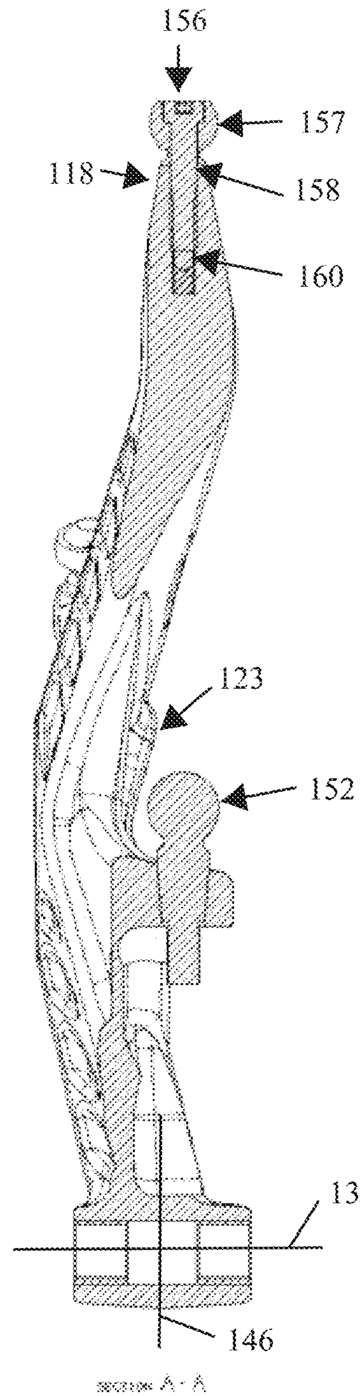

FIG. 10C

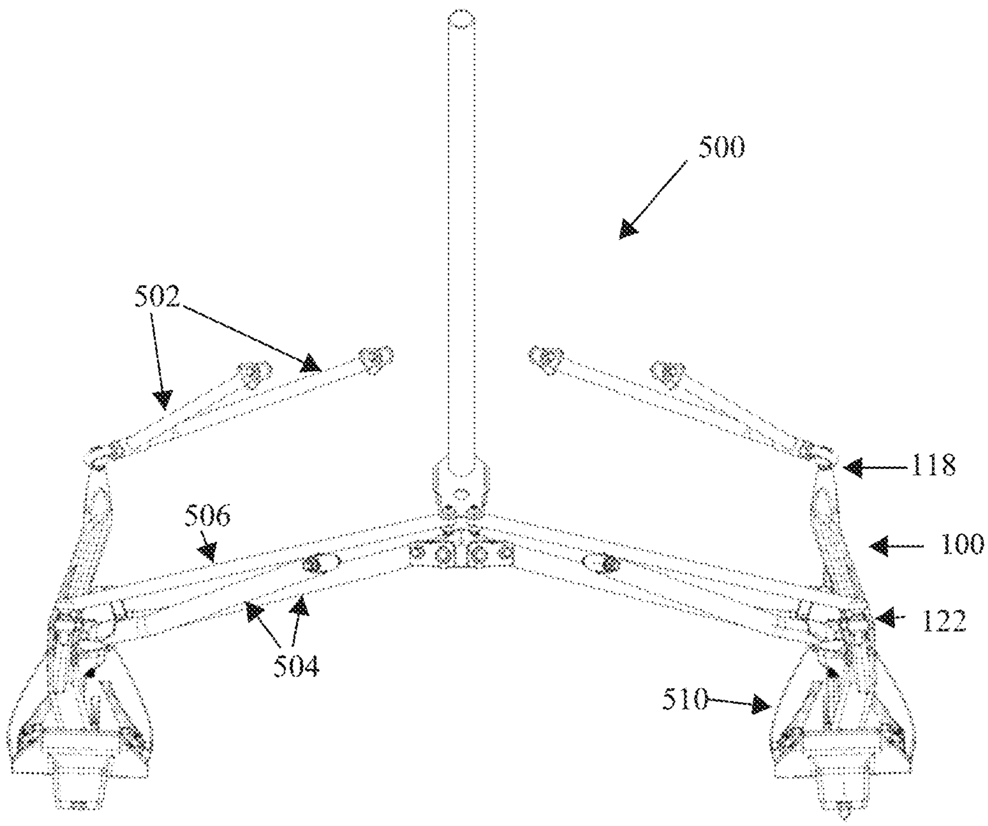

FIG. 11A

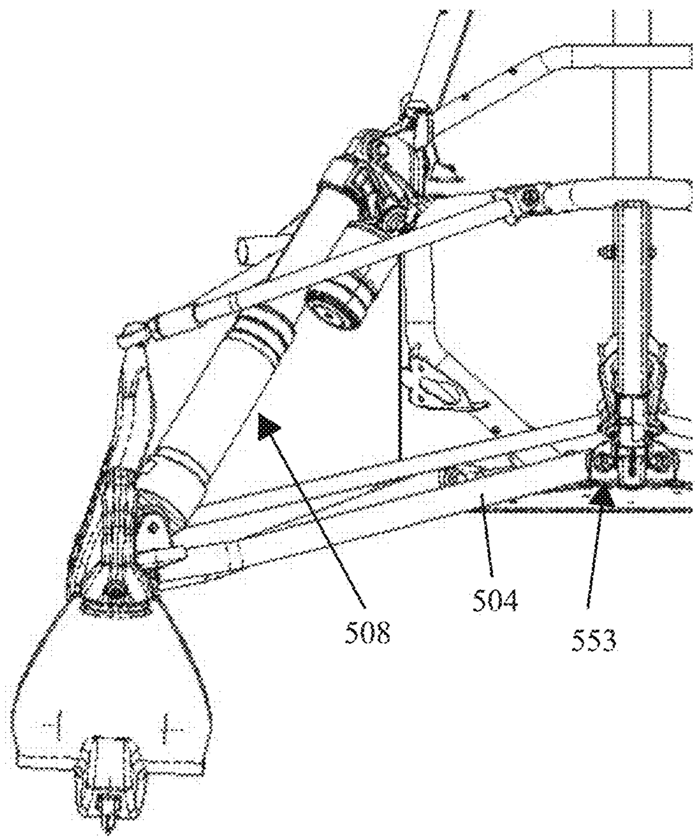

FIG. 11B

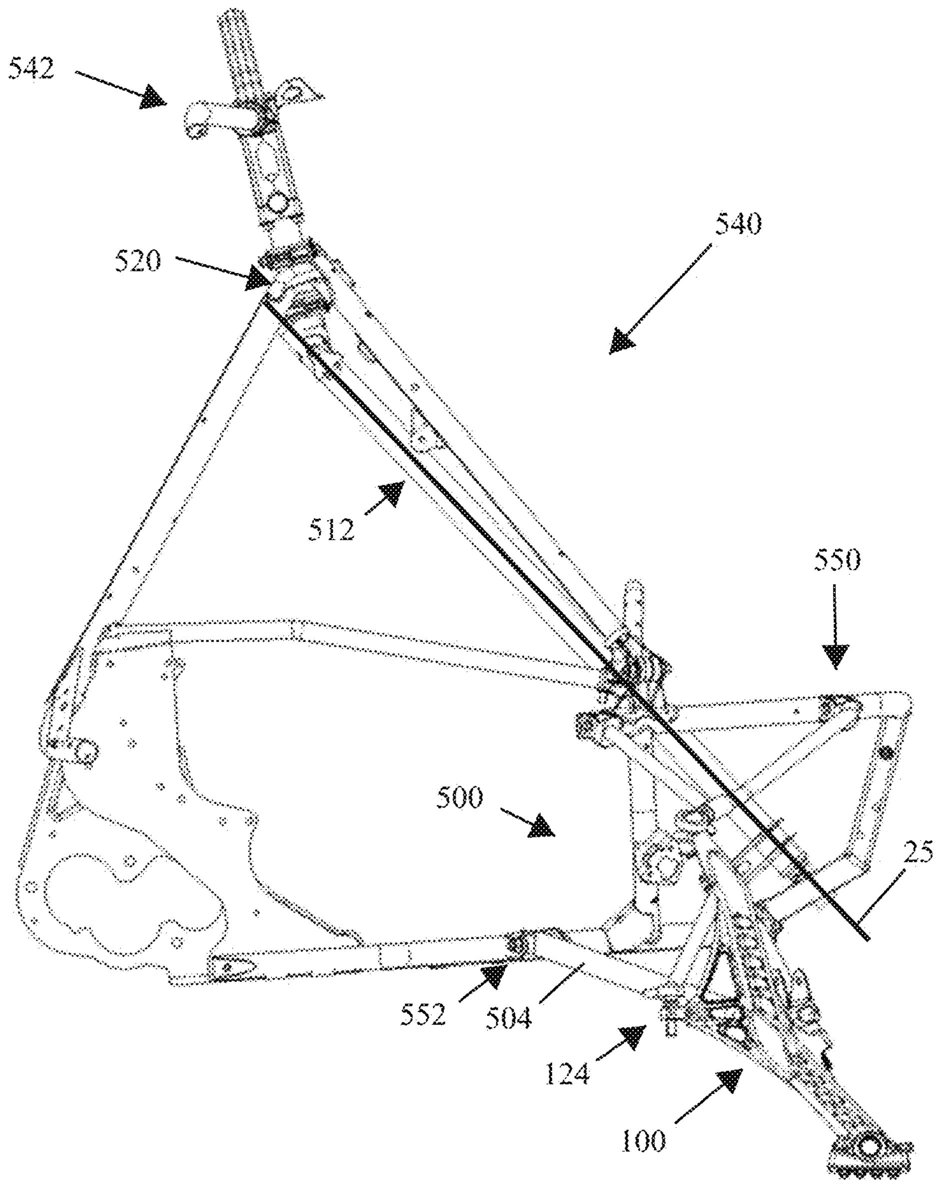

FIG. 12A

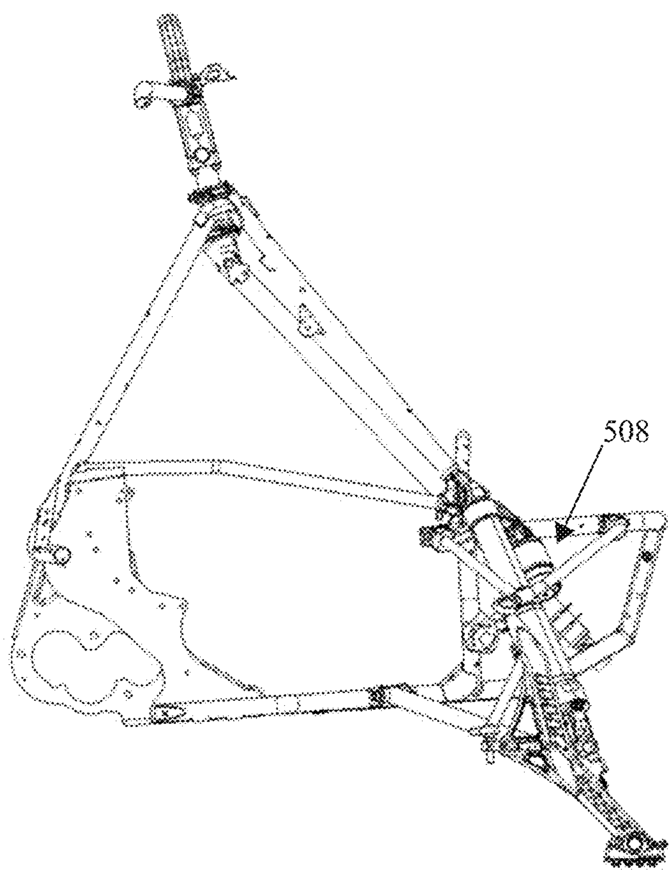

FIG. 12B

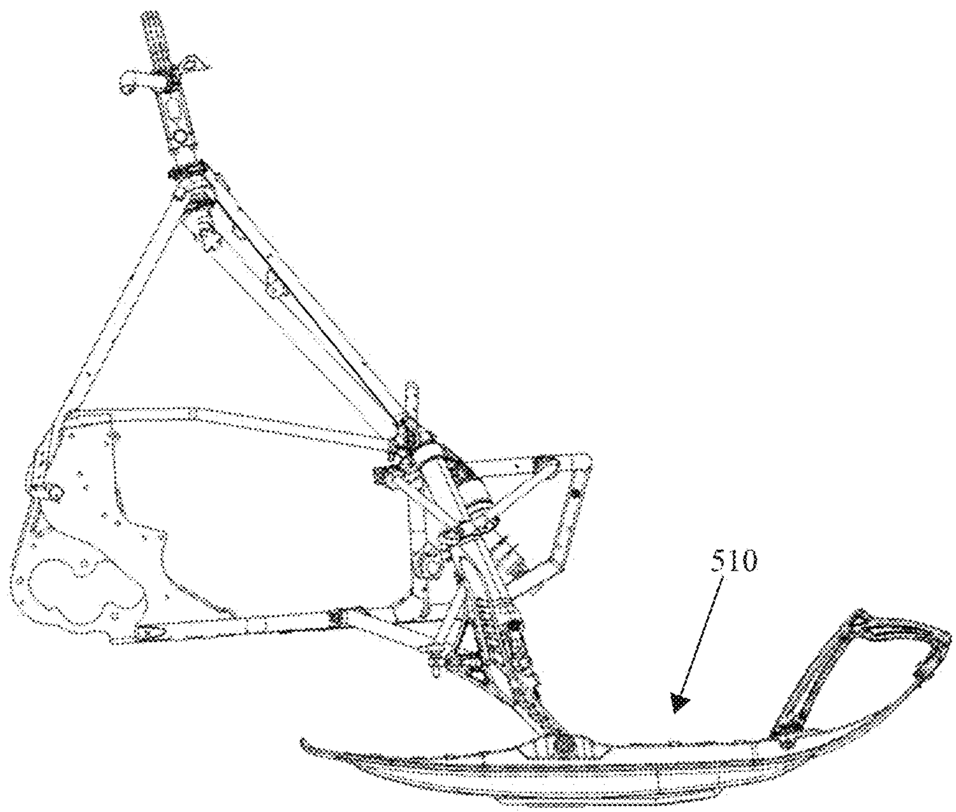

FIG. 12C

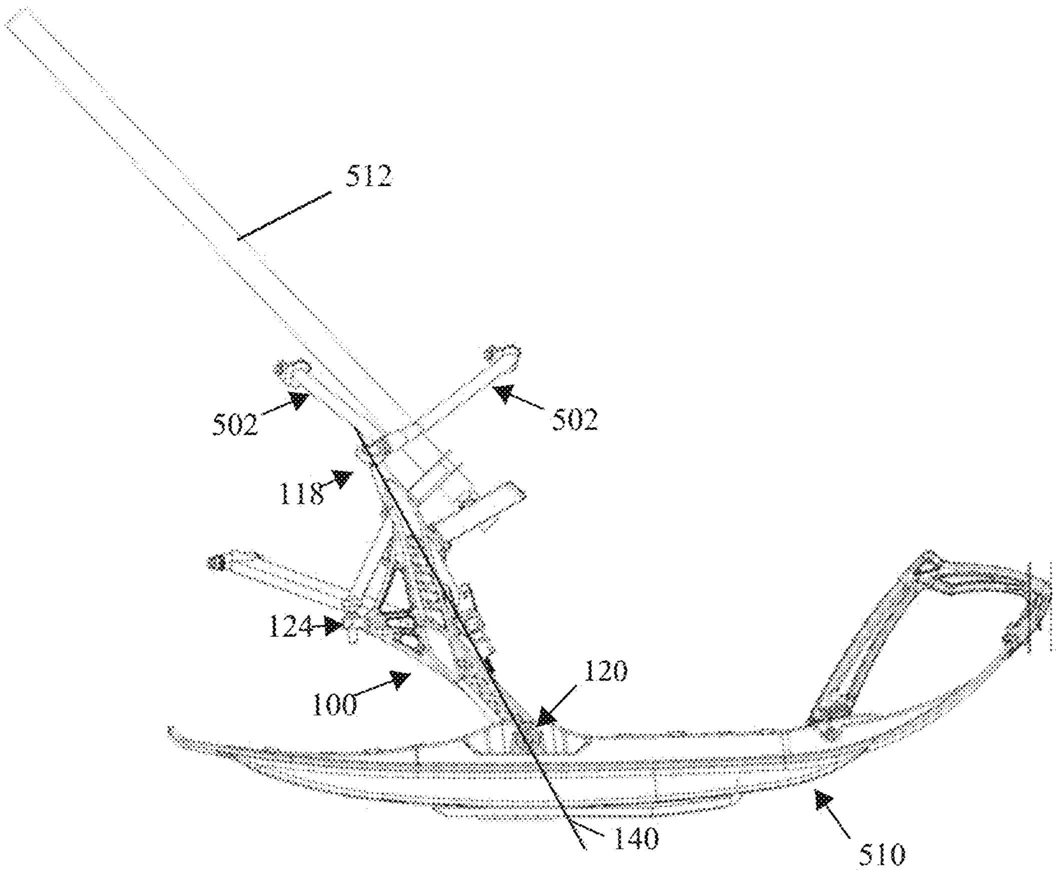

FIG. 12D

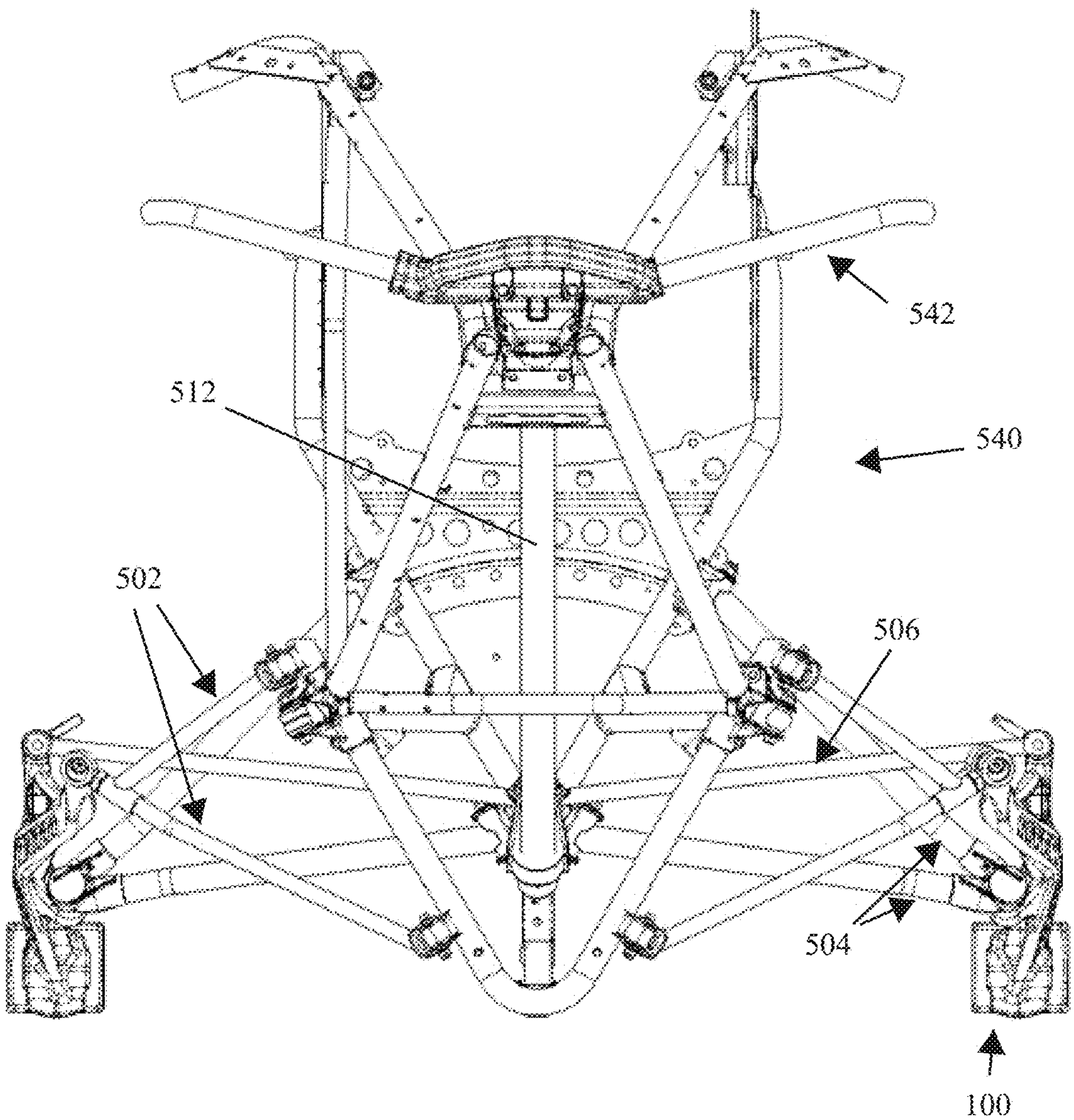

FIG. 13A

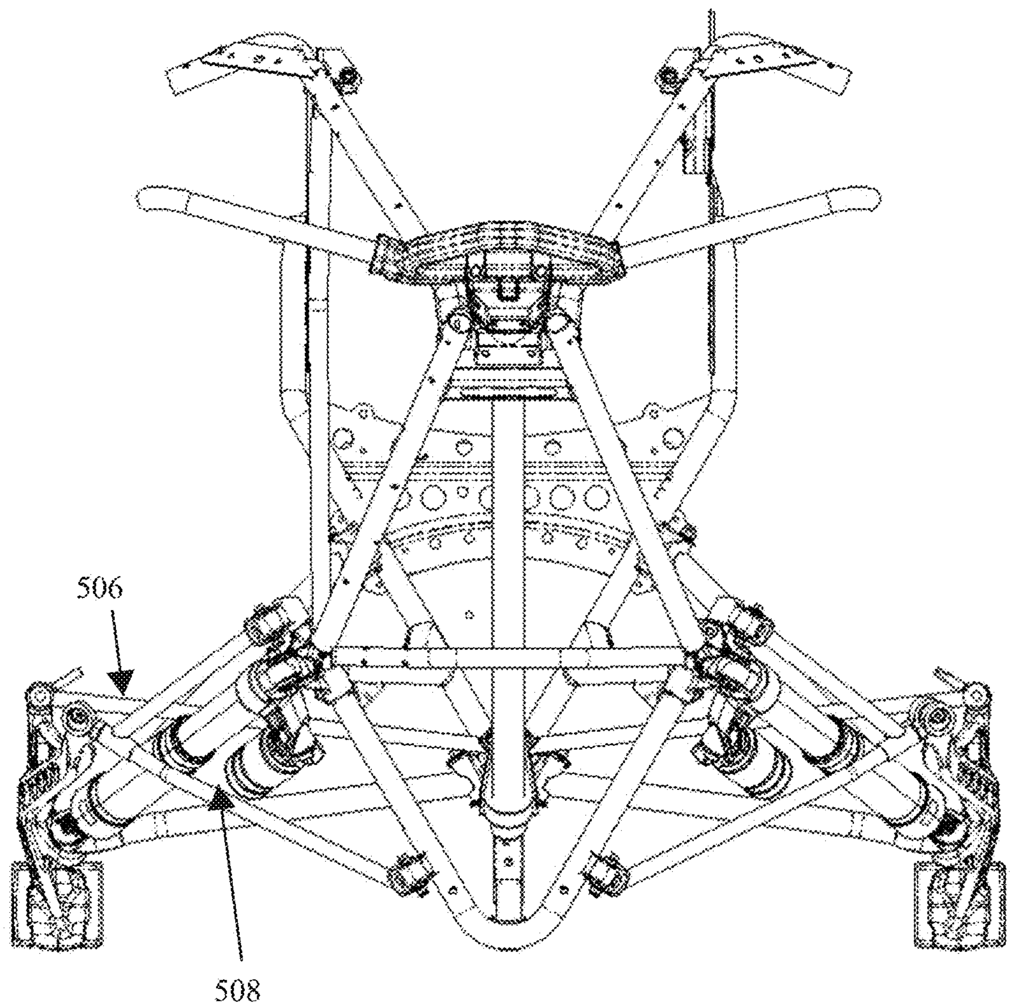

FIG. 13B

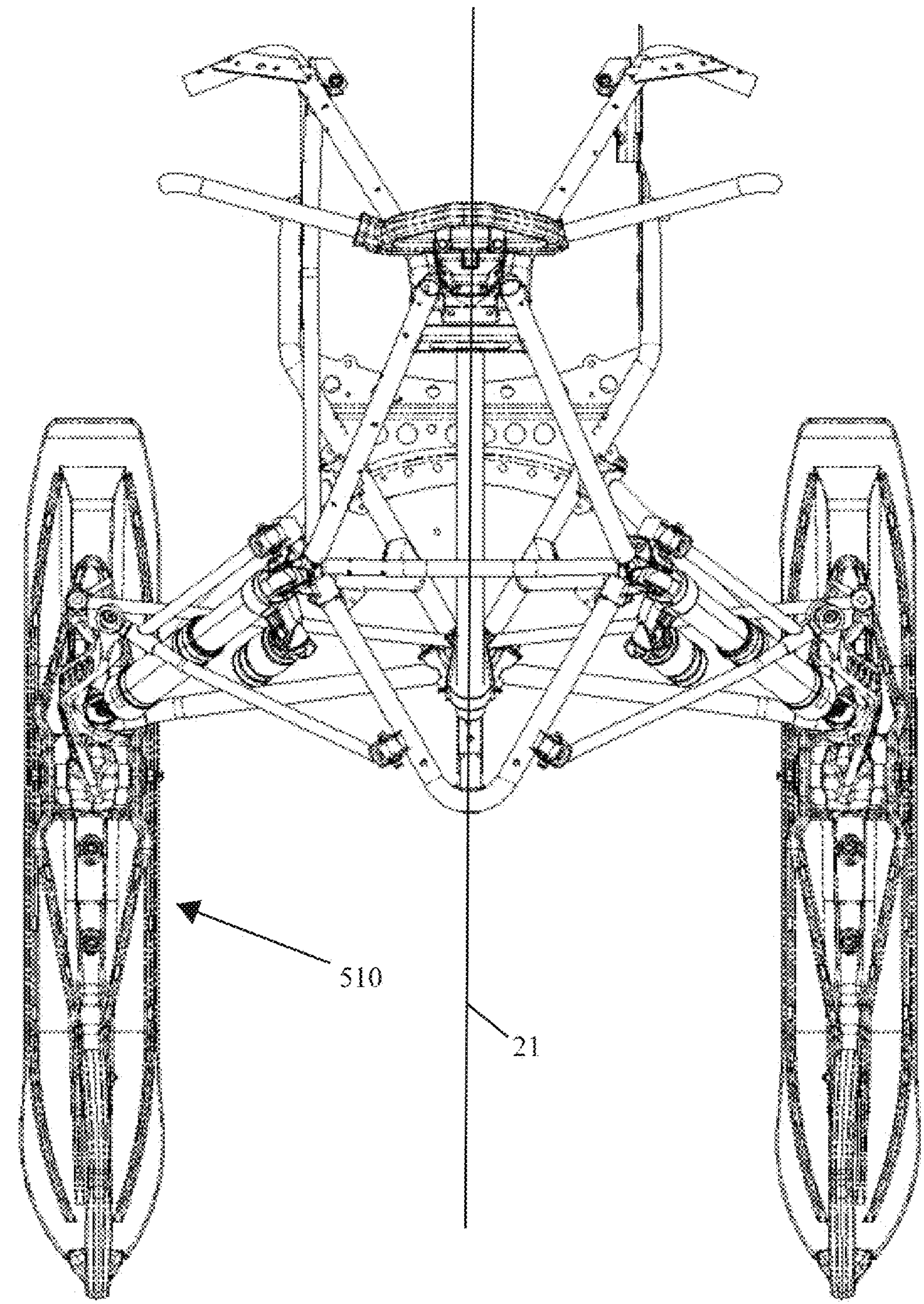

FIG. 13C

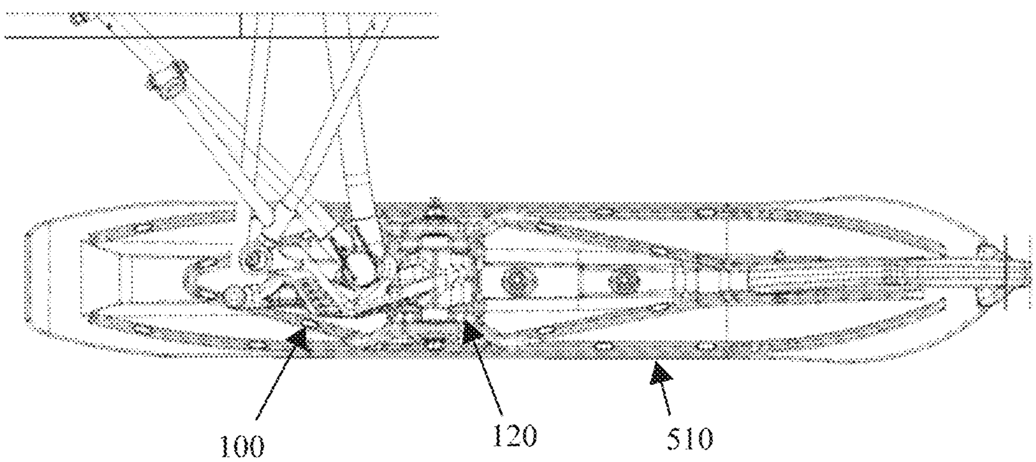

FIG. 13D

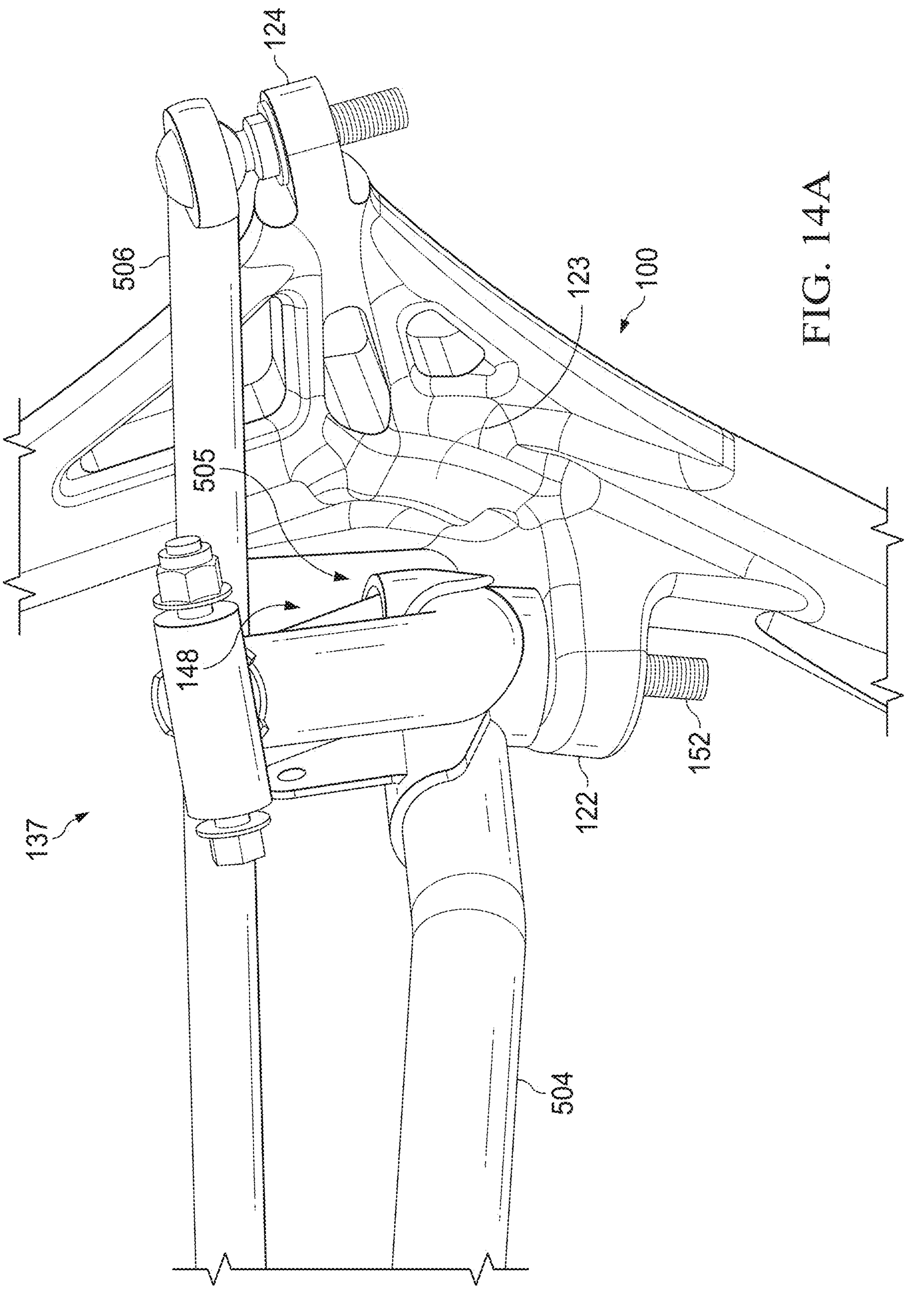

FIG. 14A

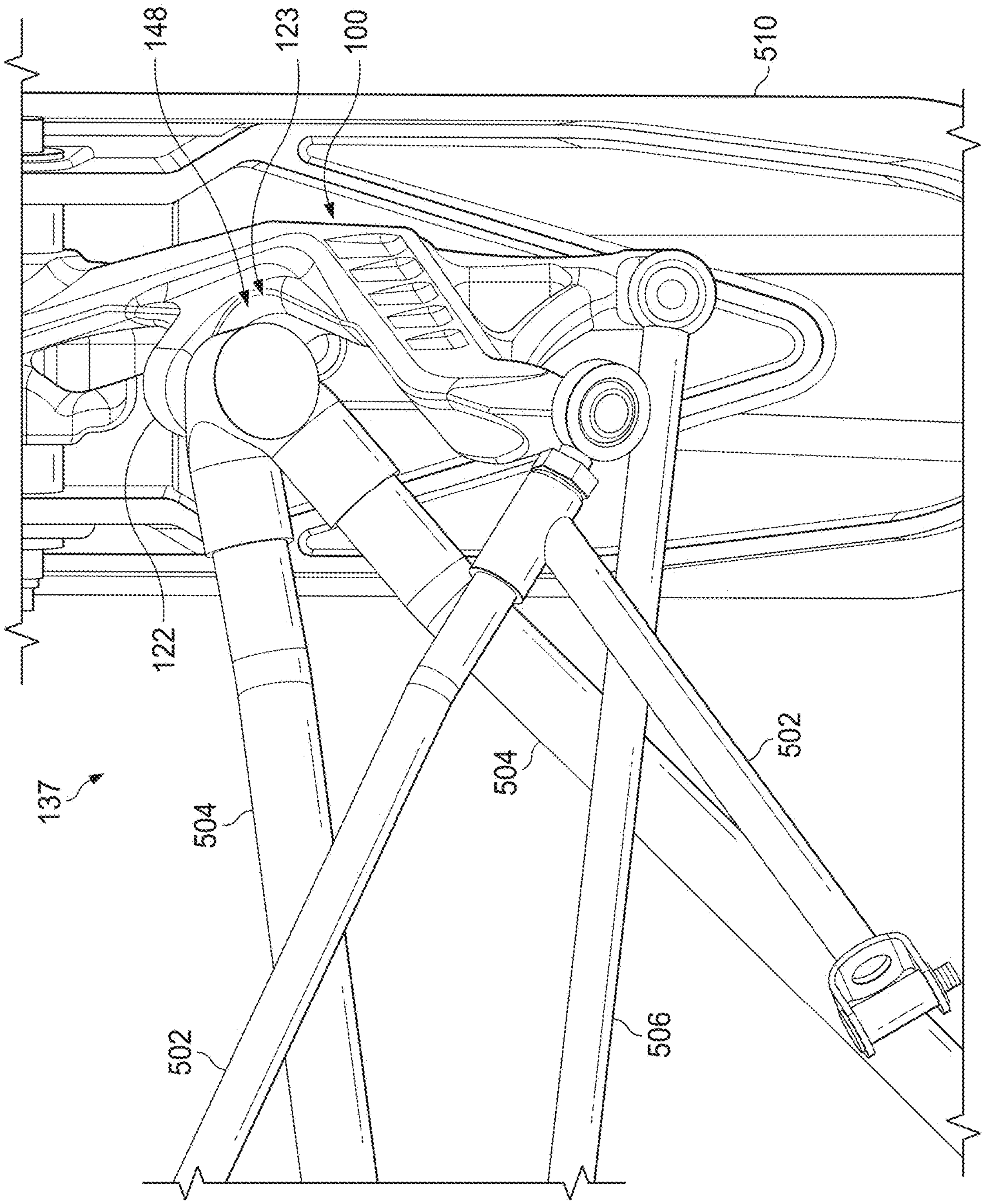

FIG. 14B

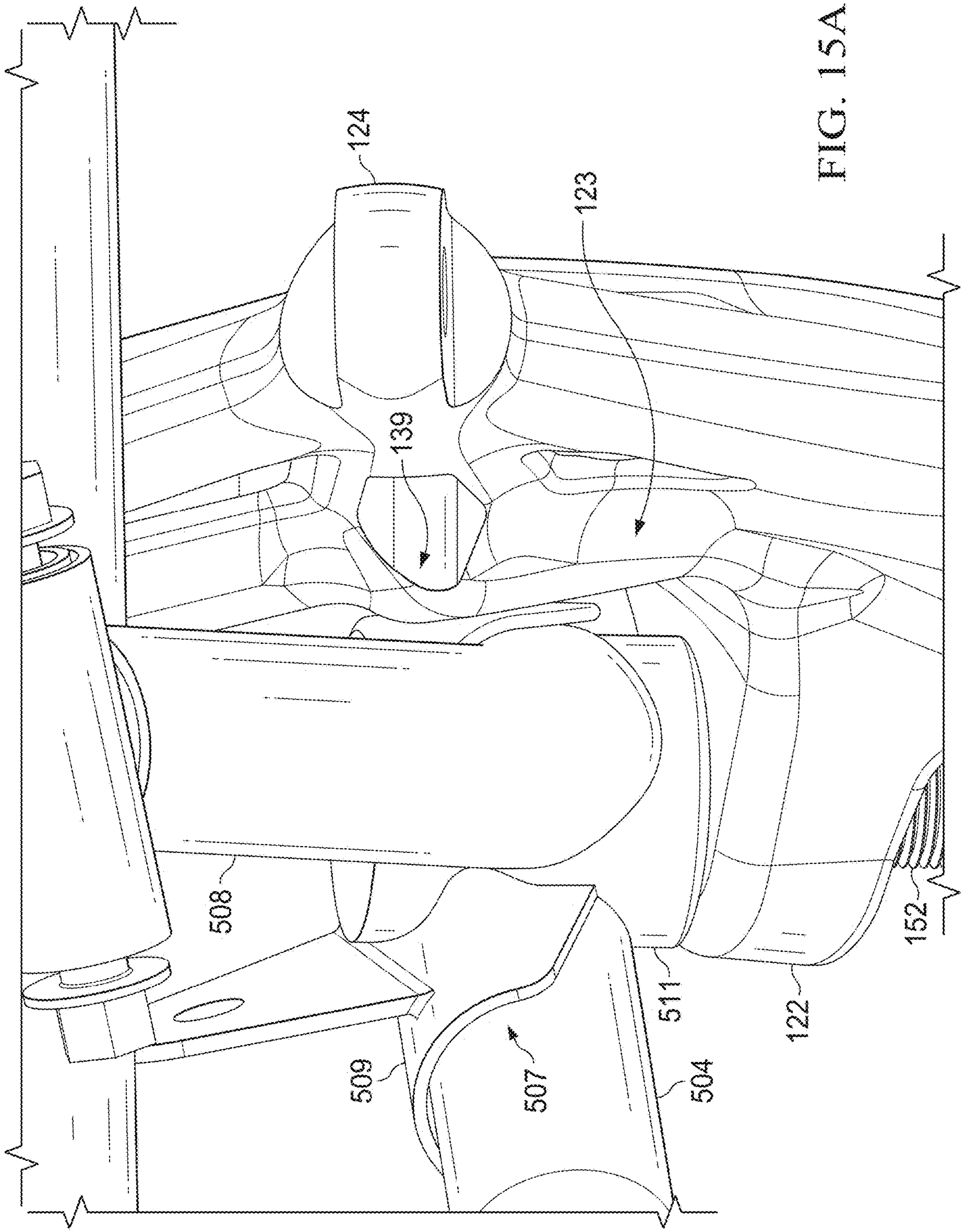

FIG. 15A

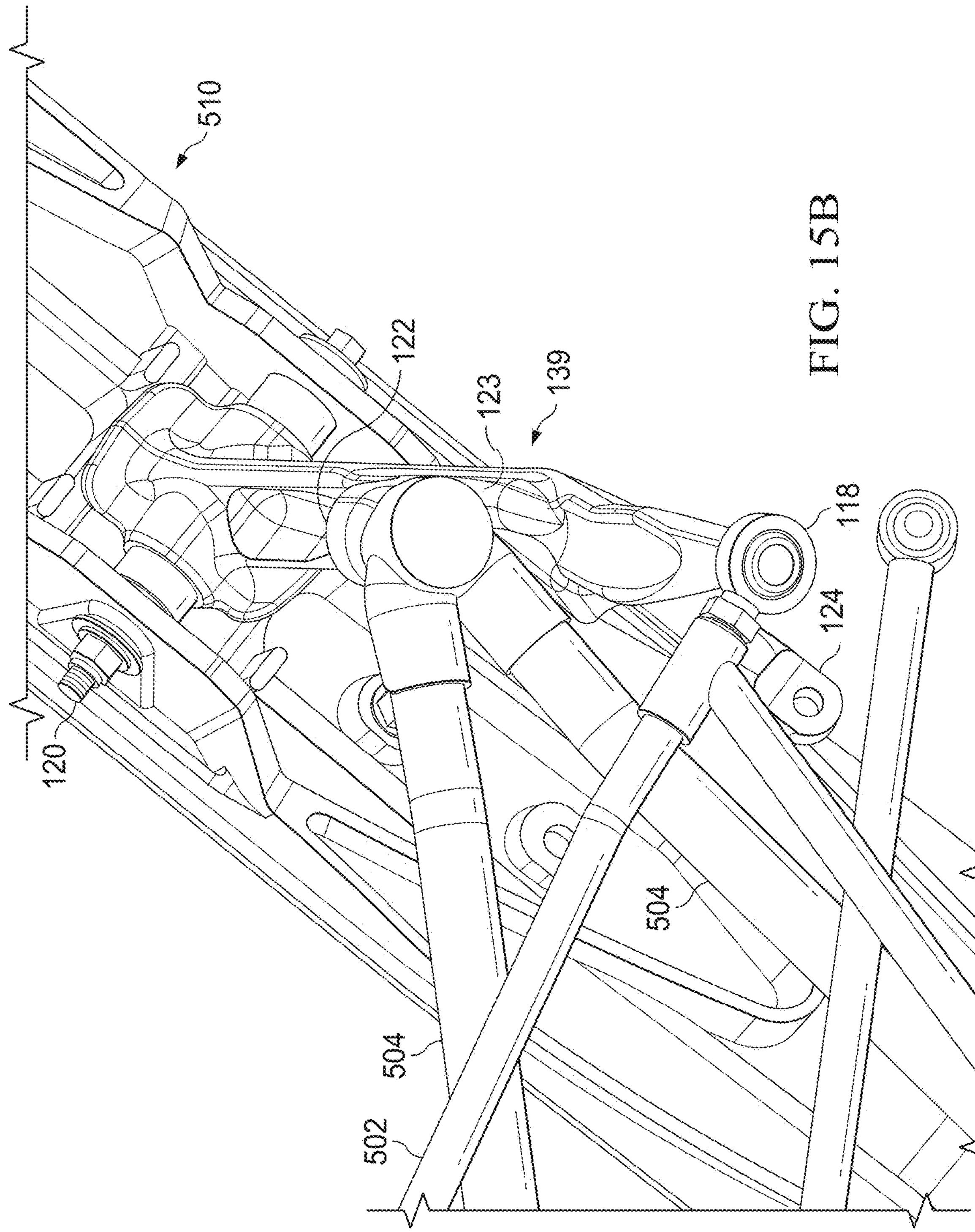

FIG. 15B

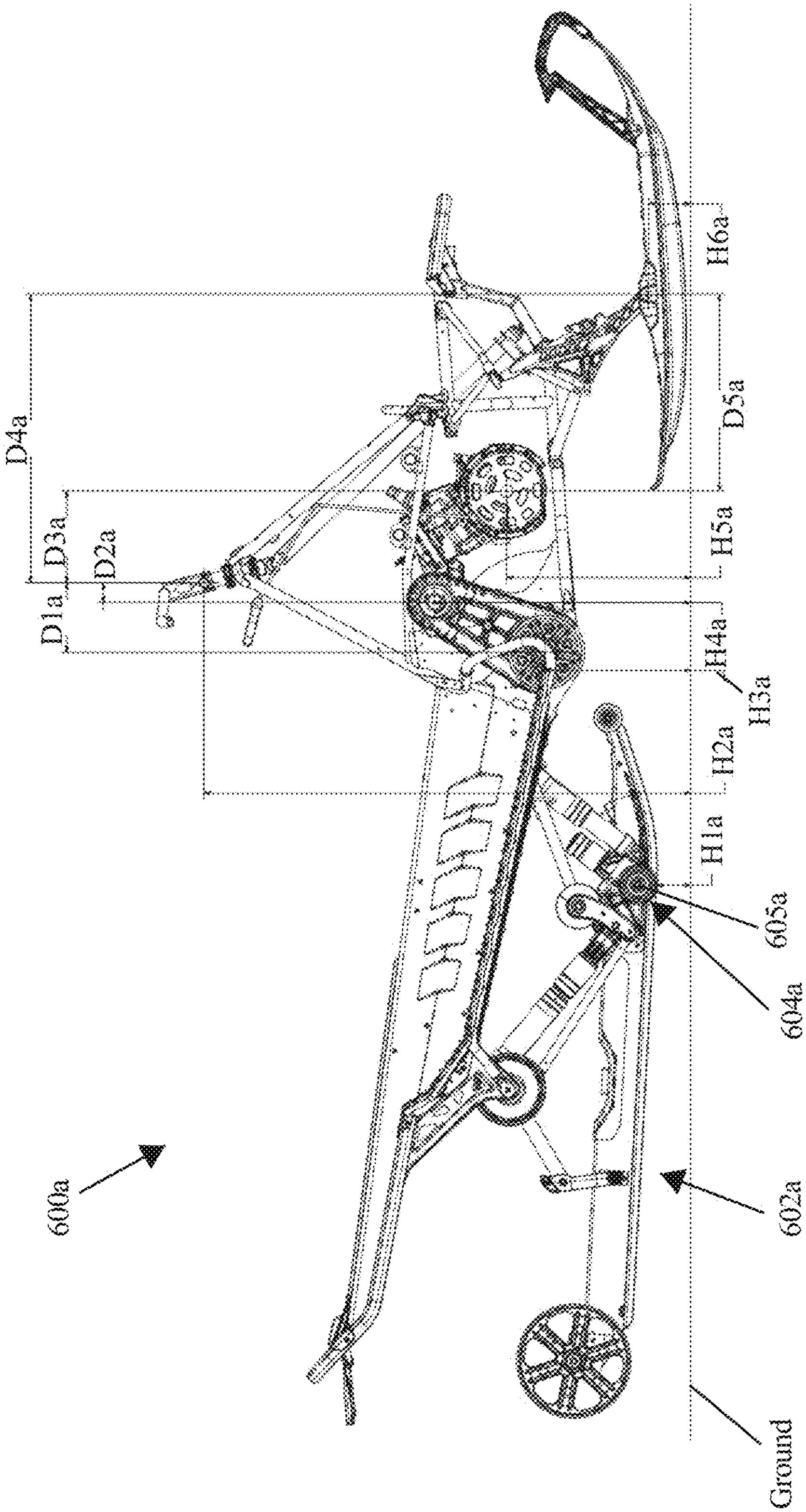
600a
602a
604a
605a
D1a
D2a
D3a
D4a
D5a
H1a
H2a
H3a
H4a
H5a
H6a
Ground

FIG. 16A

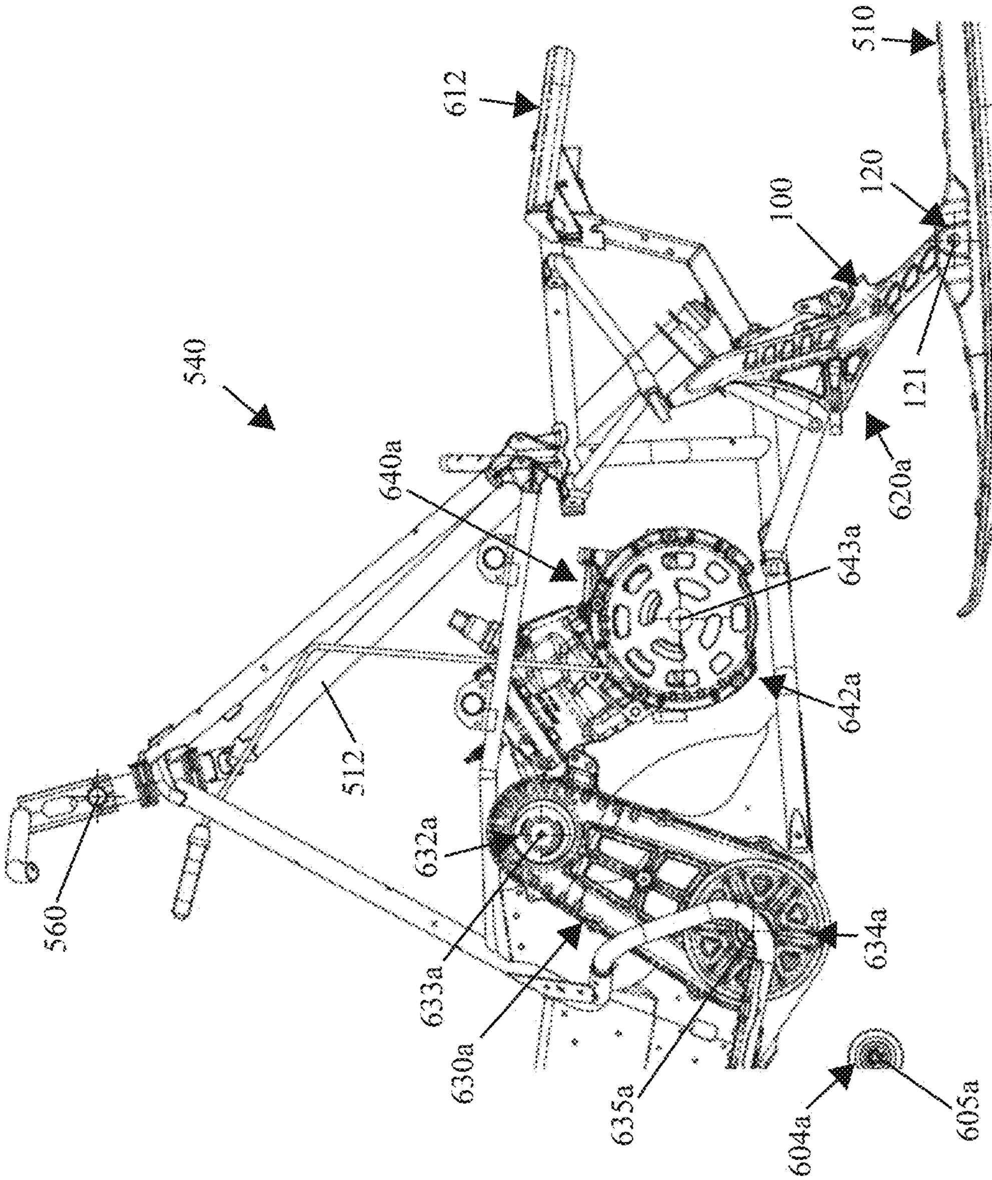
540
612
510
100
120
121
620a
640a
643a
642a
512
632a
560
633a
630a
634a
635a
604a
605a

FIG. 16B

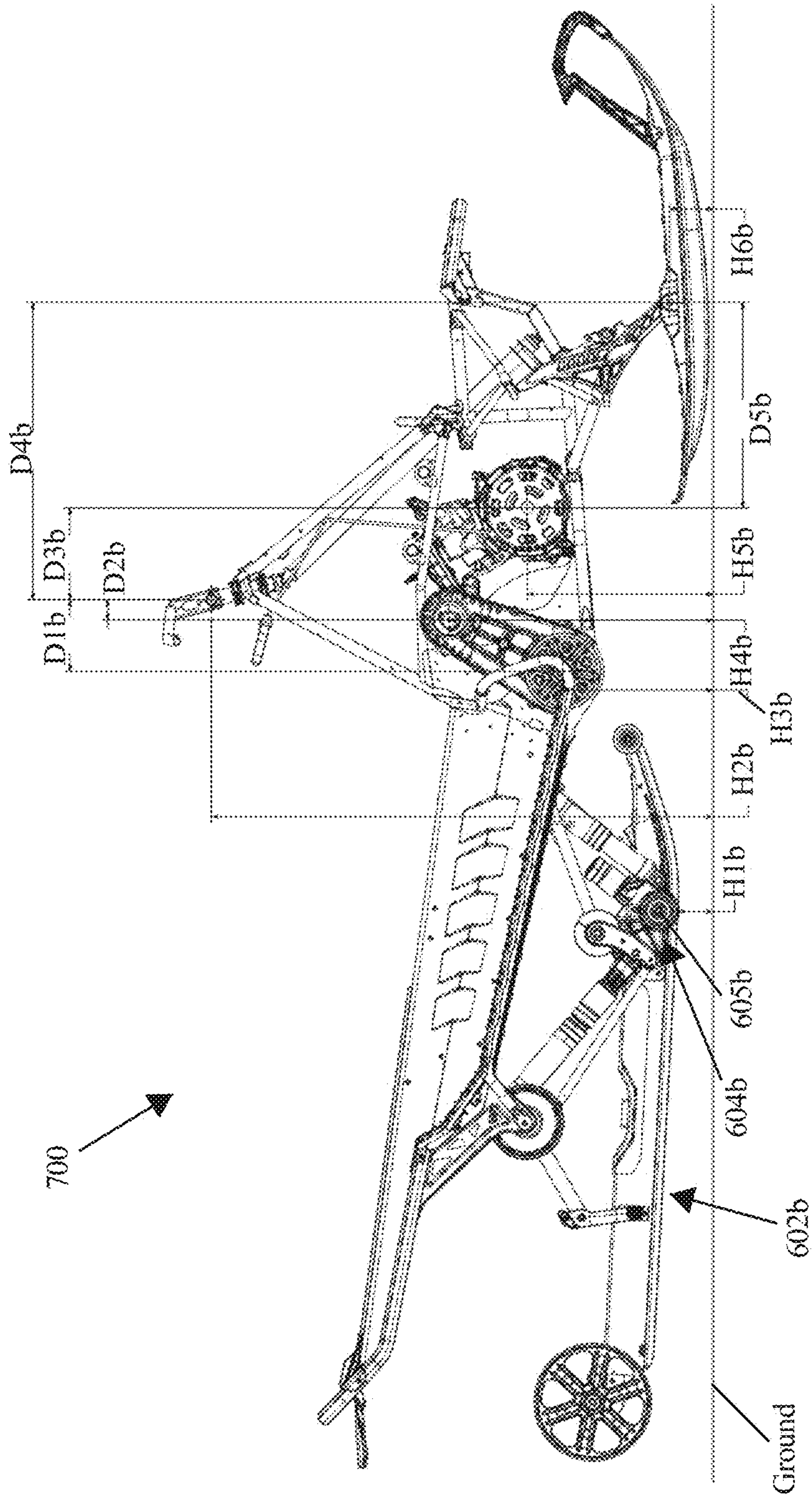
700
D4b
D3b
D2b
D1b
D5b
H6b
H5b
H4b
H3b
H2b
H1b
605b
604b
602b
Ground

FIG. 17A

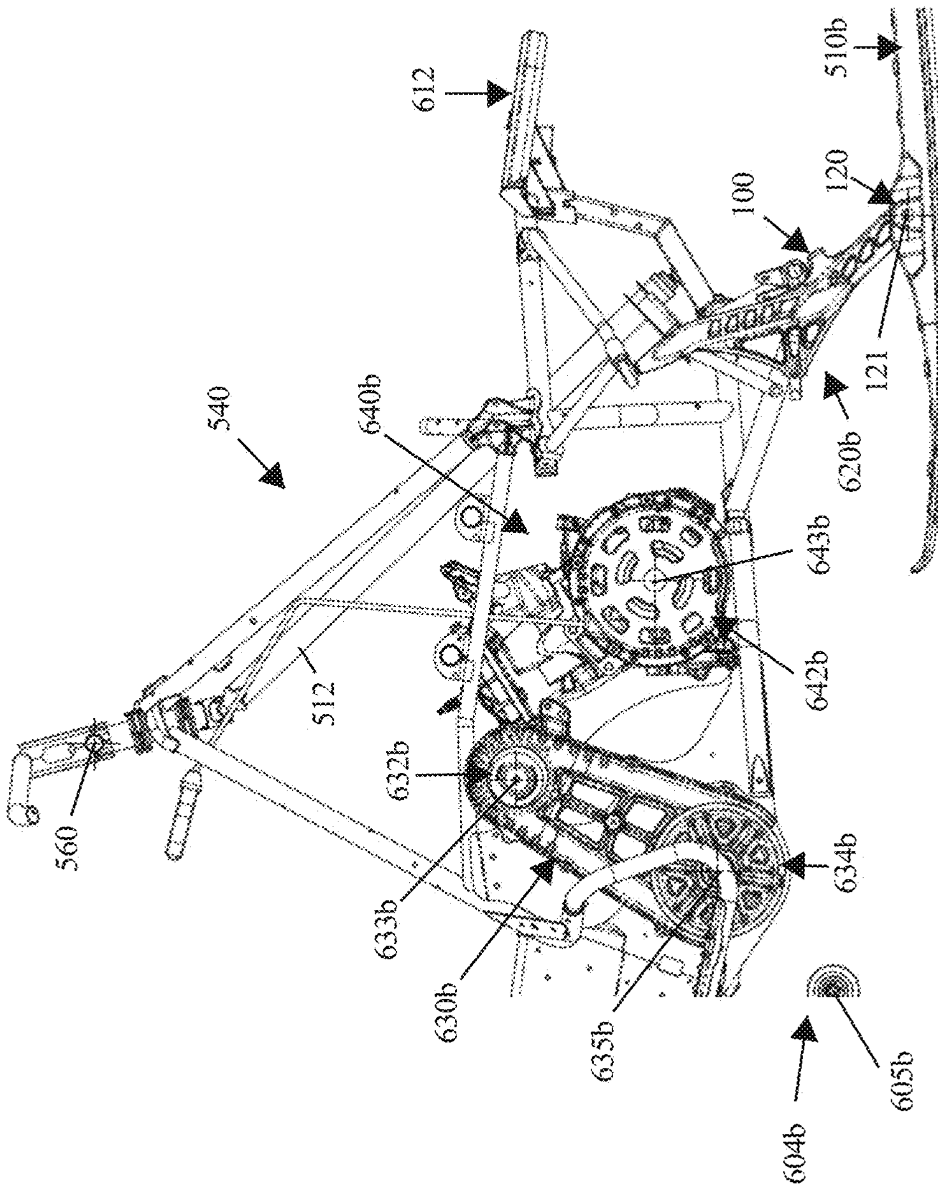
540
612
510b
100
120
640b
620b
121
643b
642b
512
632b
560
634b
633b
630b
635b
604b
605b

FIG. 17B

SPINDLE FOR A RECREATIONAL VEHICLE

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 17/988,304, filed on Nov. 16, 2022, which claims the benefit of and priority to U.S. Provisional Application No. 63/404,841, filed Sep. 8, 2022 and U.S. Provisional Application No. 63/310,276, filed Feb. 15, 2022. A claim of priority is made to the aforementioned applications. The disclosures of the above applications are incorporated herein by reference in their entirety.

BACKGROUND

Snowmobiles are popular land vehicles used for transportation or recreation in cold and snowy conditions. All-terrain vehicles (ATVs), side-by-side vehicles (SxS or UTVs), and other four-wheeled vehicles are utilized in both on- and off-road recreational and productive activities.

In general, a snowmobile has a chassis on or around which the various components of the snowmobile are assembled. Typical snowmobiles include skis for steering a seat, handlebars, and an endless track for propulsion mounted to a central chassis. The skies serve to facilitate steering as well as to provide flotation of the front of the snowmobile over the snow in which it is operated. The skis may be pivoted to steer the snowmobile, for example, by turning the handlebars. The skis support the front of the snowmobile using a suspension system that may include suspension or connecting arms mounted to the snowmobile chassis that attach to and support a spindle. Each spindle may be attached to a ski to form the operative link in the steering system whereby movement of the handlebars causes rotation of the spindles, which causes the skis to turn.

Additionally, four-wheelers such as ATVs and UTVs can utilize one or more spindles. Although this disclosure generally discusses snowmobiles, methods and structures discussed herein in the context of snowmobiles may also be used with four-wheelers having wheels or tires, as opposed to skis.

SUMMARY

In some embodiments, a spindle includes a body and a fin, wherein the body has at least one recess and the fin has at least one window.

Embodiments further include a spindle with a body with a triangular cross-sectional shape.

Embodiments include a spindle that has a body with an outboard side, wherein the outboard side has a flat surface positioned between two inboard extending portions of the body.

In at least one embodiment a spindle includes a base defining a ski mount, an upper control arm mount, a body extending between the base and the upper control arm mount, and a lower control arm mount positioned on the body between the base and the upper control arm mount; wherein at least a first portion of the body between the base and the upper control arm mount is substantially flat along an outboard edge.

In some embodiments, a spindle includes: a base including a ski mount defining an axis of rotation; an upper control arm mount; a lower control arm mount; a tie rod mount including a fin extending therefrom; a body defining a leading edge extending between the base and the upper

control arm mount, wherein a first portion of the leading edge extending from the base to adjacent the lower control arm mount extends along a first line that intersects a horizontal plane extending through the ski mount axis of rotation forward of the ski mount axis of rotation, wherein a second portion of the leading edge extending from adjacent the lower control arm mount to adjacent an upper connection between the fin and the body extends along a second line that intersects the horizontal plane rearward of the ski mount axis of rotation. Optionally the body further includes a third portion of the leading edge extending from adjacent the upper connection between the fin and the body to the upper control arm mount extends along a third line that intersects the horizontal plane forward of the ski mount axis of rotation.

In other embodiments, a spindle includes: a base including a ski mount defining an axis of rotation; an upper control arm mount; a lower control arm mount; a body defining a leading edge comprising a complex shape extending from the base to the upper control arm mount, wherein a first portion of the leading edge extending from the base to adjacent the lower control arm mount extends along a first line that intersects a horizontal plane extending through the ski mount axis of rotation forward of the ski mount axis of rotation, wherein a second portion of the leading edge extending from a point on the body between the lower control arm mount and the upper control arm mount extends along a second line that intersects the horizontal plane rearward of the ski mount axis of rotation.

In additional embodiments, a spindle includes: a base including a ski mount defining an axis of rotation; an upper control arm mount; a lower control arm mount; a body defining a leading edge extending between the base and the upper control arm mount, wherein a first portion of the leading edge extending from the base to adjacent the lower control arm mount extends along a first line that intersects a horizontal plane extending through the ski mount axis of rotation, wherein a second portion of the leading edge extending from adjacent the lower control arm mount to a point on the body between the upper control arm mount and the lower control arm mount extends along a second line that intersects the horizontal plane outboard of where the first line intersects the horizontal plane, and optionally wherein a third portion of the leading edge extending from the point to the upper control arm mount extends along a third line that intersects the horizontal plane outboard of where the first line intersects the horizontal plane.

BRIEF DESCRIPTION OF DRAWINGS

This written disclosure describes illustrative embodiments that are non-limiting and non-exhaustive. Reference is made to illustrative embodiments that are depicted in the figures, in which:

FIG. **1**A illustrates an outboard side view of a spindle, according to some embodiments of this disclosure.

FIG. **1**B illustrates an outboard side view of a spindle, according to some embodiments of this disclosure.

FIG. **2**A illustrates a top view of the spindle according to some embodiments.

FIG. **2**B illustrates a top view of the spindle according to some embodiments.

FIG. **3** illustrates a bottom view of the spindle, according to some embodiments.

FIG. **4**A is a perspective outboard front side view of the spindle, according to some embodiments of this disclosure.

FIG. **4**B is a perspective outboard front side view of the spindle, according to some embodiments of this disclosure.

FIG. **5** is a front view of the spindle, according to some embodiments of this disclosure.

FIG. **5**A is a cross-sectional perspective top view of the spindle taken at line A-A, according to some embodiments of this disclosure.

FIG. **5**B is a cross-sectional perspective top view of the spindle taken at line B-B, according to some embodiments of this disclosure.

FIG. **5**C is a cross-sectional perspective top view of the spindle taken at line C-C, according to some embodiments of this disclosure.

FIG. **5**D is a cross-sectional perspective top view of the spindle taken at line D-D, according to some embodiments of this disclosure.

FIG. **5**E is a cross-sectional perspective top view of the spindle taken at line E-E, according to some embodiments of this disclosure.

FIG. **5**F is a front view illustrating an alternative form of the spindle body, according to some embodiments of this disclosure.

FIG. **6** is a perspective inboard rear side view of the spindle, according to some embodiments of this disclosure.

FIG. **7** is an inboard side view of the spindle, according to some embodiments of this disclosure.

FIG. **8**A is a front view of the spindle, according to some embodiments of this disclosure.

FIG. **8**B is a rear view of the spindle, according to some embodiments of this disclosure.

FIG. **9**A is a side view of the spindle, according to some embodiments of this disclosure.

FIG. **9**B is a side view of the spindle, according to some embodiments of this disclosure.

FIG. **9**C is a top view of the spindle, according to some embodiments of this disclosure.

FIG. **10**A is an outboard side view of the spindle showing the fastener to be inserted into the upper control arm mount, according to some embodiments of this disclosure.

FIG. **10**B is a side view of the spindle with the fastener inserted into the upper control arm mount, according to some embodiments of this disclosure.

FIG. **10**C is a cross-sectional view of the spindle with the fastener inserted into the upper control arm mount taken at line A-A, according to some embodiments of this disclosure.

FIG. **11**A is a rear view of the suspension system, according to some embodiments of this disclosure.

FIG. **11**B is a front view of a portion of the suspension system, according to some embodiments of this disclosure.

FIG. **12**A is a side view of the spindle attached to a frame, according to some embodiments.

FIG. **12**B is a side view of the spindle attached to a frame, according to some embodiments.

FIG. **12**C is a side view of the spindle attached to a frame, according to some embodiments.

FIG. **12**D is a side view of the spindle attached to a frame, according to some embodiments.

FIG. **13**A is a front view of the frame without a shock or a ski, according to some embodiments.

FIG. **13**B is a front view of the frame including the shock, according to some embodiments.

FIG. **13**C is a top view of the frame including the ski, according to some embodiments.

FIG. **13**D is a top view of the ski, according to some embodiments.

FIG. **14**A is a rear view illustrating a first position of the suspension relative to the spindle, according to some embodiments.

FIG. **14**B is an overhead view illustrating a first position of the suspension relative to the spindle, according to some embodiments.

FIG. **15**A is a rear view illustrating a second position of the suspension relative to the spindle, according to some embodiments.

FIG. **15**B is an overhead view illustrating a second position of the suspension relative to the spindle, according to some embodiments.

FIG. **16**A is a side view of the snowmobile with the track removed, according to some embodiments.

FIG. **16**B is an enlarged view of a portion of the snowmobile, according to some embodiments.

FIG. **17**A is a side view of the snowmobile with the track removed, according to some embodiments.

FIG. **17**B is an enlarged view of a portion of the snowmobile, according to some embodiments.

DETAILED DESCRIPTION

Embodiments of the present disclosure describe a spindle, a suspension system including one or more spindles, and recreational vehicles utilizing a suspension system including one or more spindles. Examples of recreational vehicles include snowmobiles, snow bikes, and four-wheelers such as all-terrain vehicles (ATVs) and side-by-side vehicles (SxS or UTVs).

A spindle as disclosed herein that includes a body with one or more mounts for securing a suspension component and a ground engaging member thereto. The body of the spindle may include one or more of a leading edge, a triangular cross-sectional shape, and/or an outboard edge/side that includes a flat surface. Illustrative benefits of a spindle disclosed herein may include being light, streamlined, having improved handling, experiencing reduced drag in the snow, glancing off the snow, and/or being able to withstand the forces experienced in use when attached to a suspension system. In one aspect, a spindle as disclosed herein may be incorporated into a snowmobile that may be ridden in deep snow or used for side hilling. When a snowmobile with a spindle as disclosed herein is used for side hilling, the flat surface of the spindle may contact the snow. In another aspect, the spindle is configured to deflect or otherwise shed snow during operation which may decrease the amount of drag experienced by the spindle while traversing through snow.

Referring to FIGS. 1A-9C, views of a spindle **100**, according to an embodiment of this disclosure, are shown. As discussed below in greater detail with reference to FIGS. **10**-**17**, the spindle **100** may be coupled to a suspension of a snowmobile and may be utilized with different snowmobile embodiments. The snowmobile includes a longitudinal axis/centerline **21** (see e.g., FIG. **13**C). In at least one embodiment, the spindle **100** includes a body **102**, a fin **128**, an upper control arm mount **118**, a base **119** that includes a ski mount **120**, a lower control arm mount **122**, and/or a tie rod mount **124** (see e.g., FIG. **1**A).

In some implementations, the base **119** is rectangular shaped. The base **119** includes a base longitudinal axis, extending from the leading edge to the trailing edge of the base **119**, and forms a part of a vertical plane **146** (see e.g., FIGS. **2**B, **3**, **5**F, and **8**A). The longitudinal axis of the base **119** (represented by vertical plane **146**) is perpendicular/orthogonal to the long axis/axis of rotation **13** of the ski mount **120** (see e.g., FIG. **10**C; see also FIG. **9**B where the long axis **13** extends into the page). When the spindle **100** is viewed from above, the base longitudinal axis (represented by vertical plane **146**) may be positioned between a vertical plane **144** that extends through the upper control arm mount **118** and the lower control arm mount **122** and a vertical plane **3** that extends through the tie rod mount **124** and is parallel to the vertical plane **144** (see e.g., FIG. **2**B). Similarly, when the spindle **100** is viewed from the front or back, vertical plane **146** is positioned outboard to vertical plane **144** (see e.g., FIG. **8**A).

The spindle body **102** includes an upper portion **114**, a lower portion **116**, a leading edge **106**, a trailing edge **108**, an outboard side/edge **110**, and an inboard side/edge **112** (see e.g., FIGS. **1**A, **3**, **4**A, and **5**). In some embodiments, the upper portion **114** of the spindle body **102** extends between the upper control arm mount **118** and the lower control arm mount **122**, and the lower portion **116** extends between the lower control arm mount **122** and the ski mount **120** (see also FIGS. **2**A, **5**A, and **7**). In a further embodiment, the lower control arm mount **122** extends forward at an oblique angle to base longitudinal axis **146**. In one example, the lower control arm mount **122** extends inward (see e.g., FIGS. **2**A and **5**).

The leading edge **106**, trailing edge **108**, outboard side **110**, and inboard side **112** extend from the upper control arm mount **118** down to the base **119** (see e.g., FIGS. **1**A, **2**A, **3**, and **5**). The inboard side **112** and the outboard side **110** may intersect at the leading edge **106**. In some embodiments, the outboard side **110**, inboard side **112**, leading edge **106**, and/or trailing edge **108** are curvilinear. In one aspect, when the spindle **100** is attached to a snowmobile, the leading edge **106** is configured to reduce drag as the snowmobile is ridden and the spindle **100** travels through the snow. In a further aspect, the leading edge **106** is configured to point out of, or away from, the snow during side hilling with a snowmobile. In a further aspect, when the spindle **100** is attached to a snowmobile, the outboard side **110** is configured to glance off the snow instead of digging into the snow.

The leading edge **106** may also be described as comprising a complex shape extending from the base **119** to the upper control arm mount **118**, wherein a first portion of the leading edge **106** extending from the base **119** to adjacent the lower control arm mount **122** extends along a first line (see e.g., line **29** of FIG. **1**A) that intersects a horizontal plane **30** extending through the axis of rotation **13** of the ski mount **120** forward of the axis of rotation **13** of the ski mount **120**, wherein a second portion of the leading edge **106** extending from a point on the spindle body **102** between the lower control arm mount **122** and the upper control arm mount **118** extends along a second line (see e.g., line **28** of FIG. **1**A) that intersects the horizontal plane **30** rearward of the axis of rotation **13** of the ski mount **120**. It is to be understood that the leading edge **106** may extend continuously along the front of the body **102**, or may be comprised of two or more separated or discontinuous sections.

The leading edge **106**, as viewed from the outboard side, may be described as having a first/lower portion **116** extending from the base **119** to adjacent the lower control arm mount **122** and a second portion **114** extending from adjacent the lower control arm mount **122** to adjacent an upper connection between the fin **128** and the spindle body **102** (see e.g., FIG. **1**A). The first portion **116** may extend along a first line (e.g. line **29**) that intersects a horizontal plane **30** extending through the axis of rotation **13** of the ski mount **120** to a position forward of the axis of rotation **13** of the ski mount **120**. The second portion **114** may extend along a second line (e.g., line **28**) that intersects the horizontal plane **30** rearward of the axis of rotation **13** of the ski mount **120**. The leading edge **106** may further include a third portion extending from adjacent the upper connection between the fin **128** and the spindle body **102** to the upper control arm mount **118** that extends along a third line **27** that intersects the horizontal plane **30** forward of the axis of rotation **13** of the ski mount **120**.

The leading edge **106**, as viewed from the front, may be described as extending between the base **119** and the upper control arm mount **118** and including a first portion extending from the base to adjacent the lower control arm mount (along e.g., line **15** of FIG. **8**A) and a second portion of the leading edge **106** extending from adjacent the lower control arm mount **122** to a point on the spindle body **102** between the upper control arm mount **118** and the lower control arm mount **122** (along e.g., line **14** of FIG. **8**A). The first portion of the leading edge **106** may extend along the line **15** that intersects the horizontal plane **30** extending through the axis of rotation **13** of the ski mount **120**. The second portion of the leading edge **106** extends along the line **14** that intersects the horizontal plane **30** outboard of where the line **15** intersects the horizontal plane **30**. The leading edge **106** may further include a third portion extending from the point to the upper control arm mount **118**. The third portion may extend along a third line that extends along the vertical plane **144** that intersects the horizontal plane **30**. In some implementations, the third line intersects the horizontal plane **30** inboard of where the first line intersects the horizontal plane **30** (see e.g., line **15** and vertical plane **144** of FIG. **8**A). In other implementations, the third line intersects the horizontal plane **30** outboard of where the first line intersects the horizontal plane **30** (not shown).

In at least one embodiment, the spindle body **102** is curvilinear (see e.g., FIG. **5**). In some embodiments, the spindle body **102** has two bends in a forward-rearward direction when viewed along the outboard side **110**. For example, when viewed from the outboard side, the leading edge **106** may include two bends (see e.g., intersection of lines **27** and **28** and intersection of line **28** and **29** of FIG. **1**A, see also FIG. **4**A). In some embodiments, the spindle body **102** has two bends in an inboard-outboard direction when viewed from the front (see e.g., FIGS. **2**A, **2**B, **4**B, and **8**A). Although shown with two bends from each view, it is to be understood that the number of bends is not limited, and the body may contain more or less than two bends in either direction.

In one example, at least a portion of the spindle body **102** is V-shaped. The arms of the V-shape may be formed by the upper portion **114** and the lower portion **116** of the spindle body **102**, as illustrated by lines **28** and **29** in FIG. **1**A and by lines **4** and **5** in FIG. **2**B. The angle between the upper and lower portions **114**, **116** may be an obtuse angle (see e.g., FIG. **1**A) or approximately 90° (see e.g., FIG. **2**B). The vertex of the V-shape may be positioned between the tie rod mount **124** and the lower control arm mount **122** (see e.g., FIGS. **1**A, **4**B, **8**B), between the upper control arm mount **118** and the lower control arm mount **122** (see e.g., FIG. **2**B), and/or adjacent to the lower control arm mount **122** (see e.g., FIG. **8**A). The vertex of the V-shape may come to a point or be flat. For example, the outboard side **110** of the spindle body **102** forms a V-shape with the flat surface **136** forming a flat vertex for the V-shape (see e.g., the top view of FIG. **2**B and the front view of FIG. **8**A).

Lines **28** and **29** of FIG. **1**A illustrate a V-shape from an outboard view with line **28** extending along the leading edge **106** of the upper portion **114** of the spindle body **102** and line

29 extending along the leading edge **106** of the lower portion **116** of the spindle body **102**. Lines **4** and **5** of FIG. **2**B illustrate a V-shape from a top view with line **4** extending along the leading edge **106** of the upper portion **114** of the spindle body **102** and line **5** extending along the leading edge **106** of the lower portion **116** of the spindle body **102**. Lines **8** and **9** of FIG. **4**B illustrate a V-shape from an outboard perspective view with line **8** extending along the leading edge **106** of the upper portion **114** of the spindle body **102** and line **9** extending along the leading edge of the lower portion of the spindle body **102**. Lines **14** and **15** of FIG. **8**A illustrate a V-shape from a front view with line **14** extending along the upper portion **114** of the spindle body **102** and line **15** extending along the lower portion **116** of the spindle body **102**. Lines **19** and **26** of FIG. **8**B illustrate a V-shape from a rear view with line **19** extending along the upper portion **114** of the spindle body **102** and line **26** extending along the lower portion **116** of the spindle body.

In some embodiments, the spindle body **102** has a curvilinear perimeter. In one example, the spindle body **102** has a triangular cross-sectional shape (see e.g., FIG. **5**A). The spindle body **102** may have a triangular cross-sectional shape along at least some of the length of the spindle body **102**. The triangular cross-sectional shape is most clearly seen by an intermediate form **101** of the spindle body **102**, as shown in FIG. **5**F. Lines **11** and **12** of FIG. **5**F illustrate a V-shape of from a top front perspective view with line **11** extending along a leading edge of the upper portion of the intermediate form **101** of the spindle body and line **12** extending along a leading edge of a lower portion of the intermediate form **101** of the spindle body **102**.

In some implementations, the spindle body **102** from the upper control arm mount **118** down to the base **119** has a v-shape or a triangular cross-sectional shape as shown in FIGS. **5**A-**5**E that is at least partially defined by the inboard side **112** and the outboard side **110** intersecting at the leading edge **106** which defines the vertex. In some implementations, one or more cross-sections of the spindle body **102** includes one or more concave sides (see e.g., FIGS. **5**C and **5**E). Concave sides may be defined by recesses **129**, **130** which may be positioned along the length of the spindle body **102**, as discussed below in greater detail.

As shown in FIGS. **5**A-E, the orientation of the leading edge **106** and the v-shape or triangle changes from the top of the spindle body **102**, arrow O**1**, down toward the bottom of the spindle body **102**, arrow O**2** (see e.g., FIGS. **5**A and E). Arrows O**1** and O**2** are orthogonal to a dashed line extending between the inboard and outboard sides of the spindle body **102**. Arrow O**1** is oriented at an acute angle to the base longitudinal axis **146**. Arrow O**2** may extend from the rear wall of the triangle through the leading edge **106** so that the arrow O**2** extends substantially perpendicular to the direction of the ski axle or axis of rotation **13** of the mount hole **126** in the ski mount **120**. In one aspect, this orientation of arrow O**2** reduces drag at that location.

In a non-limiting example, the orientation of the leading edge **106** rotates inboardly from an outboard facing direction to a forward or inboard facing direction while moving down the spindle body **102** from the upper control arm mount **118** to the base **119** (see e.g., FIGS. **5**A and E). In some implementations, the change in the orientation of the leading edge **106** while moving down the spindle body **102** is linear. In one non-limiting example, the leading edge **106** rotates approximately 10° to 30°, and optionally from 15° to 25°, and optionally 20° while moving along the spindle body **102**. As one non-limiting example, the leading edge **106** adjacent to the upper control arm mount **118** is oriented approximately 20° in an outboard direction relative to the base longitudinal axis **146** while the leading edge **106** adjacent to the base **119** is oriented approximately parallel to the base longitudinal axis **146**) (0°).

In at least one embodiment, the volume of the spindle body **102** changes while moving down the spindle body **102** from the upper control arm mount **118** to the base **119**. The volume of the spindle body **102** adjacent to the upper control arm mount **118** may be less than the volume of the spindle body **102** adjacent to the base **119**. In some embodiments, the volume of the spindle body **102** adjacent to the upper control arm mount **118** is approximately 65-85% of the volume of the spindle body **102** adjacent to the base **119**, and optionally 73-80% of the volume of the spindle body **102** adjacent to the base **119**. In one non-limiting example, the volume of the spindle body **102** adjacent to the upper control arm mount **118** is less than the volume at the bottom by a factor of 0.3—in other words if the volume at the top is 1, the volume at the bottom is 1.3. In some embodiments, the change in volume is linear. In other embodiments, the change in volume is non-linear.

In one aspect, when a spindle **100** with a v- or triangular cross-sectional shape is attached to a snowmobile, a vertex of the v- or triangle forms the spindle's leading edge **106** that leads the spindle **100** into the snow and/or sheds snow around the spindle **100** to reduce drag. A bottom flat triangle shown in FIG. **5**E is provided where the lower portion **116** is joined to the ski mount **120** The bottom flat triangle is parallel with the ski axle (or a horizontal plane extending through the axis of rotation **13** of the mount hole **126** in the ski mount **120**) to maintain a substantially triangular cross section with the leading edge **106** directly forward along the ski mount **120** and positioned along the center of the ski mount **120** (e.g., along the base longitudinal axis **146**). Due to the shape, the profile of the spindle body **102** is narrower along the forward portion of the base **119** and increases to a wider profile along a rearward portion of the base **119**.

The spindle body **102** may further include a flat surface **136**. In one example, the perimeter of the flat surface **136** is curvilinear (see e.g., FIG. **4**A). In another example, the flat surface **136** is a quadrilateral. In some embodiments, a flat surface **136** is located on the outboard side **110** of the spindle body **102** (see e.g., FIGS. **2**B and **5**), and may be positioned at least partially, and optionally entirely, outboard of the base **119**. In one example, the flat surface **136** is between two inboard/inward extending portions of the outboard side **110**. For example, the flat surface **136** is positioned between the upper portion **114** and the lower portion **116**, and the upper portion **114** of the outboard side **110** extends inward from the flat surface **136** and the lower portion **116** of the outboard side **110** extends inward from the flat surface **136** (see e.g., FIG. **2**B with lines **4** and **5** indicating the orientation of the two inward extending portions and line **6** indicating orientation of the flat surface **136** which may be parallel to the base longitudinal axis **146** and the vertical plane **144**, and perpendicular to the axis of rotation **13** of the ski mount **120**; see also FIG. **5**). The flat surface **136** may extend vertically from a point on the spindle body **102** positioned below the lower control arm mount **122** to a point on the spindle body **102** positioned above the lower control arm mount **122** (see e.g., horizontal lines **17** and **18** of FIG. **8**A). In one aspect, the flat surface **136** provides the spindle body **102** with a narrower width. Thus, when the spindle **100** is attached to a recreational vehicle, the vehicle width is narrower which may improve its ability to move between trees and/or through the snow. In another aspect, during side hilling, where typically the skis are turned away from the hill, the flat surface **136** may be the point of contact between the spindle **100** and the snow. In a further aspect, when the spindle **100** is attached to a snowmobile, the flat surface **136** is configured to glance off the snow instead of digging into the snow.

The spindle body **102** may include a steering stop **123**. In at least one embodiment, a steering stop **123** is integrated into the spindle body **102** (see e.g., FIGS. **5** and **14-15**). In some embodiments, the steering stop **123** is located along the inboard side **112** of the spindle body **102** (see e.g., FIG. **6**). In one example, the steering stop **123** is vertically positioned between the lower control arm mount **122** and the tie rod mount **124** (see e.g., FIGS. **7** and **15**). In other embodiments, the steering stop **123** is an inwardly extending, triangular shaped, portion of the spindle body **102** that is wider at the top than at the bottom. In one example, the narrower portion ends just above a top surface of the lower control arm mount **122**.

In one aspect, steering stop **123** is configured to prevent the suspension from oversteering or going beyond a desired endpoint. For example, the steering stop **123** may prevent the turning of the spindle beyond approximately 180 degrees. In some embodiments, the steering stop **123** may be configured to contact a face **505** of the knuckle **507** (see e.g., FIGS. **14**A and **15**A). The material used for the knuckle **507** and the spindle **100** may be resistant to deformation. In a further aspect, the steering stop **123** is configured to provide a hard stop just before the full steering point is reached. In some embodiments, the stop angle is the same throughout the stroke of the shock. In another aspect, when the spindle **100** is attached to a suspension system, the steering stop **123** may prevent the steering from binding up while riding. In an additional aspect, the steering stop **123** may eliminate or reduce buckling/compression of the tie rod **506**, thereby making it easier to return the steering back to center.

FIGS. **14**A-B illustrate a first steering position **137** where the skis **510** are substantially parallel to the snowmobile longitudinal axis **21**. For example, the ski **510** in the first steering position may be oriented approximately 180° relative to the snowmobile centerline **21**. In another example, the ski **510** in the first steering position **137** may be oriented with a slight inward bias at the front. In one aspect, the inward bias may prevent or inhibit darting. In the first steering position **137**, there is a space **148** between the coupling housing/knuckle **505** of the front suspension and the steering stop **123**.

FIGS. **15**A-B illustrate a stop position **139** where the ski **510** is positioned at an angle to the snowmobile longitudinal axis **21**. The ski angle in the stop position **139** may be at approximately 135° to 145° relative to the snowmobile longitudinal axis **21**. In the stop position **139**, a face **505** of the knuckle **507** may contact the steering stop **123** (see e.g., FIG. **15**A).

In some embodiments, the spindle body **102** further includes a recess **129** positioned between the lower control arm mount **122** and the ski mount **120** (see e.g., FIGS. **2**A and **6-7**). The recess **129** may have a curvilinear perimeter along surface of the spindle body **102**. In some embodiments, the recess **129** may have a triangular shaped upper perimeter where the end adjacent to the lower control arm mount **122** is narrower than the end adjacent to the ski mount **120** (see e.g., FIG. **6**). In another configuration, recess **129** is U-shaped (see e.g., FIGS. **5**E and **6**). In some embodiments, the walls of the recess **129** may be angled inwards from the surface of the spindle body **102** down to the bottom of the recess **129**. When viewed from the front, a rear side wall of the recess **129** may be viewable (see e.g., FIG. **8**A). In one example, the lower control arm mount **122** extends over the recess **129**. In one aspect, the recess **129** reduces the weight of the spindle **100**.

In at least one embodiment, the spindle body **102** further includes one or more recesses **130** (see e.g., FIGS. **4**A and **5**A). The recesses **130** may be positioned along the outboard side **110** of the spindle body **102**. In one aspect, the one or more recesses **130** provides the spindle body **102** with an irregular outer surface. In one example, the upper portion **114** has a plurality of recesses **130** and the lower portion has a plurality of recesses **130** (see e.g., FIG. **4**A). In an additional example, a plurality of recesses **130** is positioned above and/or below the flat surface **136**. In one example, a first group of recesses **130** are positioned above the flat surface **136** and a second group of recesses **130** are positioned below the flat surface **136** (see e.g., FIG. **4**A). In another example, the upper portion **114** has five recesses **130** positioned long the outboard side **110**, the lower portion **116** has four recesses **130** positioned along the outboard side **110**, and one recess **129** positioned between the lower control arm mount **122** and the ski mount **120** (see e.g., FIG. **5**). The recess **130** may have any size. For example, recesses **130** located in the upper portion may be shallower and/or smaller than recesses **130** located in the bottom portion or vice-versa (see e.g., FIG. **8**A). The recess **130** may have any shape. In some embodiments, the recess **130** is wedge-shaped (see e.g., FIG. **4**A). In one configuration, the leading end of the wedge shape is the narrow end, and the trailing end of the wedge shape is the wide end. For example, recess **130***a* and recess **130***b* have a first end **131***a* with a greater depth than the second end **131***b* (see e.g., FIG. **4**A).

The fin **128** extends backward from the spindle body **102** (see e.g., FIG. **1**A). Thus, the fin **128** may be described as a rear fin. In some embodiments, the fin **128** is attached to the trailing edge **108** of the spindle body **102** (see e.g., FIGS. **3** and **6**). In one aspect, the fin **128** has a length greater than its width (see e.g., FIGS. **6-7**). In other words, the length of the fin **128** as it extends backward is greater than its width between the outboard and inboard sides of the fin **128**. In one example, the fin **128** has a rearward extent about 3-4× greater than its side extent. In another aspect, the fin **128** extends along only a portion of the spindle body **102**.

In one example the fin **128** extends from a location adjacent to a bottom of the upper control arm mount **118** to a location adjacent to a bottom end of the flat surface **136** (see e.g., FIG. **1**A). In some embodiments, the fin **128** includes the tie rod mount **124**. In one example, the tie rod mount **124** separates an upper portion **125** and a lower portion **127** of the fin **128** (see e.g., FIG. **1**A-B). The upper portion **125** may extend inward from the tie rod mount **124** towards the upper control arm mount **118**. As one non-limiting example, the upper portion **125** may be oriented at the same angle as the spindle body **102** (see e.g., line **19** of FIG. **8**B). In an illustrative example, the entire upper portion **125** of the fin **128** may be shielded by the upper portion **114** of the spindle body **102** as shown in FIG. **5**. The lower portion **127** may be oriented parallel to base longitudinal axis **146** or extend in an outboard direction as the lower portion **127** extends from the tie rod mount **124** towards the ski mount **120**. In an illustrative example, the entire lower portion **127** of the fin **128** may be shielded by the spindle body **102** as shown in FIG. **5**.

The tie rod mount **124** may be positioned between the inboard side **112** and the outboard side **110** of the spindle body **102** (see e.g., line **20** of FIG. **8**B). Therefore, the spindle body **102** is positioned directly forward of the tie rod mount **124**. As shown in FIGS. **2**A, **5** and **6**, the spindle body

102 is positioned directly forward of the tie rod mount **124** and may have a width that is wider than the width of the tie rod mount **124**. In one aspect this configuration shields the tie rod mount **124** and limits direct exposure of the tie rod mount **124** to the snow.

In some implementations, the fin **128** has a V-shape. In a non-limiting example, the V-shape of the fin **128** may be similar to the V-shape of the spindle body **102**. For example, when viewed from the rear, the fin **128** and the spindle body **102** have similar V-shapes with line **19** extending along the trailing edge of the upper portion **125** of the fin **128** and line **26** extending along the trailing edge of the lower portion **127** of the fin **128** (see e.g., FIG. **8**B).

In some embodiments, the tie rod mount **124** extends backward from the spindle body **102** in a longitudinal direction parallel to the base longitudinal axis **146** (see e.g., FIG. **2**B). In one aspect, by extending backward from a fin **128** that has a similar orientation as the spindle body **102**, the tie rod mount **124** is tucked behind the spindle body **102** (see e.g., FIG. **8**B). In another aspect, a majority of the spindle body **102** is positioned toward the outboard side of body **102** (see, vertical plane **144** of FIGS. **8**A-B). Thus, the tie rod mount **124** is not visible when the spindle **100** is viewed from the front (see e.g., FIG. **5**). When the spindle **100** is attached to a snowmobile, tucking or otherwise shielding the tie rod mount **124** behind the spindle body **102** reduces/prevents the tie rod end and/or the ball joint and fastener **154** from dragging in the snow.

In at least one embodiment, the fin **128** has at least one window **132**. In one example, the fin **128** has three windows **132***a*, **132***b*, **132***c* (see e.g., FIG. **9**A). In a further example, the fin **128** includes a window **132***b* positioned between the tie rod mount **124** and the spindle body **102**. Each window **132** may have any suitable size and shape. In one aspect, the window **132** reduces the weight of the spindle **100** while maintaining the ability of the spindle **100** to support loads experienced during use. In one embodiment, the fin **128** has a reduced thickness area or recess instead of a window **132** (not shown).

In some embodiments, a support member **134** separates adjacent windows (see e.g., FIG. **4**A). In one example, the support member **134** is V-shaped with a window **132** positioned inside the V (see e.g., line **1** and line **2** of FIG. **1**B). The V-shape may be made by a single support member **134** or two support members **134**. When viewed from the side, the upper portion **125** and/or lower portion **127** of the fin **128** may also be oriented at an angle to support member **134** to form a V-shape (see e.g. lines **22** and **24** of FIG. **1**B). The fin **128** may be described as having an upper triangular shaped portion defined by the upper portion **125**, support member **134** and the spindle body **102** (see e.g. triangle defined by lines **1**, **22**, and **23**); a middle triangular shaped portion defined by support member **134** and the spindle body **102** (see e.g., triangle defined by lines **1**, **2**, and **23**), and a lower triangular shaped portion defined by the lower portion **127**, support member **134** and the spindle body **102** (see e.g., triangle defined by lines **2**, **23**, and **24**).

In at least one embodiment, a steering axis **140** extends through the upper control arm mount **118**, the lower control arm mount **122**, and the ski mount **120** (see e.g., FIG. **7**). In this exemplary configuration, the bulk of the spindle material (majority of the spindle body **102**) is positioned behind the steering axis **140**. The steering axis **140** may form a part of the vertical plane **144** (see e.g., FIGS. **8**A-B).

In additional embodiments, the upper control arm mount **118**, lower control arm mount **122**, and ski mount **120** are aligned along a vertical plane **144** and the tie rod mount **124** is positioned outboard of the vertical plane **144**. In this example, the vertical plane **144** is positioned inboard relative to the vertical plane **146** (see e.g., FIGS. **8**A-B). In these embodiments, the tie rod mount **124** is positioned closer to the outboard side than the upper control arm mount **118**, lower control arm mount **122**, and the ski mount **120**. In one example, the tie rod mount **124** extends rearward, parallel to the vertical plane **146** (see also FIGS. **2**B and **3**).

In some embodiments, when viewed from above, the upper control arm mount **118** is positioned between the lower control arm mount **122** and the tie rod mount **124** (see e.g., FIG. **2**B). The upper control arm mount **118** may be positioned inboard to the base longitudinal axis **146**. In one example, the upper control arm mount **118** lies on a vertical plane **144** that is parallel to the vertical plane **146** that includes the longitudinal axis of the base **119** (see also FIG. **8**A). In one example, the upper control arm mount **118** is closer in a longitudinal direction to the tie rod mount **124** than to the lower control arm mount **122**, and the lower control arm mount **122** is closer in a longitudinal direction to the ski mount **120** than to the upper control arm mount **118** (see e.g., FIGS. **1**B-C). In some embodiments, when viewed from the side, the tie rod mount **124** is positioned in a vertical direction between the upper control arm mount **118** and the lower control arm mount **122**, and the lower control arm mount **122** is positioned in a vertical direction between the tie rod mount **124** and the ski mount **120** (see e.g., FIGS. **1**A and **5**). In one example, at least a portion of each mount **118**, **120**, **122**, **124** is viewable when the spindle **100** is viewed toward the inboard and outboard directions (see e.g., FIGS. **1**A and **5**).

FIGS. **9**A-C identifies lengths L, V, W of the spindle **100** and an angle A. In this illustrative example, the upper control arm mount **118**, the lower control arm mount **122**, and the tie rod mount **124** each form a part of a ball joint, as discussed below in greater detail (see FIGS. **10**A-C). Although many of the lengths L**1**–L**3** and V**1**–V**3** are measured from the center of the ball **157** of one ball joint to the center of the ball **157** of another ball joint, for simplicity, reference will be made to the mounts **118**/**122**/**124**. Angle A is the angle of the steering axis **140** to the line indicating the lower bound of V**2**, at the long axis **13** of the ski mount **120** when the suspension is in a fully extended state and the skis are directed forward. In one example, angle A is about 25° to 35°. In FIG. **9**A, the spindle **100** is tilted to an upright position where an axis through the upper control arm mount **118** is perpendicular to the ground. In this orientation, the spindle **100** has a length L extending from a trailing edge of the rear tie rod mount **124** to a leading edge of the base **119** that includes the ski mount **120**. In FIG. **9**B. the spindle **100** has the same angle as it would be when attached to a front suspension when the suspension is in a fully extended state and the skids are directed forward (see e.g., FIG. **12**D). In this orientation, lengths L**1**, L**2**, L**3**, V**1**, V**2**, and V**3** are identified. FIG. **9**C is a top view of the spindle **100** with widths W and W**1** identified.

As shown in FIG. **9**B, L**1** represents the length between the upper control arm mount **118** and the lower control arm mount **122**, L**2** represents the length between the tie rod mount **124** and the lower control arm mount **122**, L**3** represents the length between the lower control arm mount **122** and the ski mount **120**, L**1**+L**3** represents the length between the upper control arm mount **118** and the ski mount **120**, and L**2**+L**3** represents the length between the tie rod mount **124** and the ski mount **120**. In some embodiments, the length from the tie rod mount **124** to the upper control arm mount **118** is less than the length from the lower control arm mount **122** to the ski mount **120**, which is less than the length from the upper control arm mount **118** to the lower control arm mount **122** ((L**2**−L**1**)<L**3**<L**1**)). In some embodiments, the longitudinal length of the spindle **100** in the upright position is less than the longitudinal length in its use orientation. In one example, the longitudinal length in the its use orientation is about 17% greater than its length in the upright position. Length L**2**+L**3**, from the rear tie rod mount **124** to the ski mount **120**, may be described as a total length. In one example, L**1** comprises about 50% to 60% of the total length and optionally 53% to 57% of the total length, L**2** comprises about 60% to 70% of the total length and optionally 63% to 67% of the total length, L**3** comprises 30% to 40% of the total length and optionally a 33% to 37% of the total length, L**1**+L**3** comprises 85% to 95% of the total length and optionally 87% to 93% of the total length, and L**2**−L**1** comprises 5% to 15% of the total length and optionally 7% to 13% of the total length.

In at least one embodiment, the lower control arm mount **122** is closer to the ski mount **120** along the steering axis **140** than to the upper control arm mount **118** (see e.g., FIG. **9**B). In one example, the length between the lower control arm mount **122** and the ski mount **120** along the steering axis **140** is 35% to 45% of the length and optionally 37% to 43% of the length between the upper control arm mount **118** and the ski mount **120** along the steering axis **140**.

As shown in FIG. **9**B, V**1** represents the vertical height between the upper control arm mount **118** and the lower control arm mount **122**, V**2** represents the vertical height between the lower A-arm mount **122** and the long axis **13** of the ski mount **120**, V**3** represents the vertical height between the tie rod mount **124** and the lower control arm mount **122**, and V**1**+V**2** represents the vertical height between the upper control arm mount **118** and the long axis **13** of the ski mount **120**. In some embodiments, the vertical length from the tie rod mount **124** to the lower control arm mount **122** is less than the vertical length from the lower control arm mount **122** to the ski mount **120**, which is less than the vertical length from the upper control arm mount **118** to the tie rod mount **124** (V**3**<V**2**<(V**1**−V**3**)) (see e.g., FIG. **9**B). Height V**1**+V**2**, measured from the upper control arm mount **118** to the ski mount **120**, may be described as a total vertical length. In one example, V**1** comprises 55% to 65% of the total vertical length and optionally 57% to 63% of the total vertical length, V**2** comprises 35% to 45% of the total vertical length and optionally 37% to 43% of the total vertical length, V**3** comprises 5% to 10% of the total vertical length, and V**1**-V**3** comprises 50% to 55% of the total vertical length.

As shown in FIG. **9**C, W represents the width of the spindle **100** measured from an inboard edge of the ski mount **120** to the flat surface **136** of the outboard edge, and W**1** represents the width of the ski mount **120** measured from the inboard edge to the outboard edge. In some embodiments, the width of the spindle **100** is greater than the width of the ski mount **120** (W**1**<W). In one example, W**1** is 10% to 20% smaller than W and optionally about 13% to 17% smaller than W.

The spindle **100** may be made of any suitable material, including, but not limited to, lightweight metals and alloys. Illustrative examples include aluminum and aluminum alloys, titanium and titanium alloys, and magnesium and magnesium alloys. In a non-limiting example, the spindle **100** may be comprised of 6061 aluminum and may be forged. It is to be understood that the spindle **100** is not limited to forgings as other methods including, but not limited to, casting, additive manufacturing, and machining may be used to fabricate the spindle **100**.

In at least one embodiment, an intermediate form **101** of the spindle **100** includes a body **113** with a base **115** where the body **113** has a triangular cross-sectional shape extending uninterrupted from the base **115** to the upper end of the body **113** (see e.g., FIG. **5**F). Lines **10**, **11**, and **12** extend along a leading edge of the intermediate form **101**. The intermediate form **101** may further include an upper integral component (not shown) and a lower integral component **117**. In some embodiments, the intermediate form **101** is a casting, but may also be forged, additive manufactured, or machined from billet. The body **113** of the intermediate form **101** may have a V-shape, may vary in volume, and/or may have a leading edge with an orientation that rotates, as discussed above for the spindle body **102**. Machining may be utilized to form the ski mount **120** in the base **115**, the upper control arm mount **118** in the upper integral component, the lower control arm mount **122** in the integral lower integral component **117**, the flat surface **136**, recess **129**, and/or one or more recesses **130**. Although described herein as an intermediate form **101**, it is to be understood that the intermediate form **101** may be secured to one or more skis and a suspension and/or frame and used as a finished spindle.

As shown in FIGS. **1**A and **2**A, the upper control arm mount **118**, ski mount **120**, lower control arm mount **122**, and/or the tie rod mount **124** define a hole **126** for attaching the spindle **100** to a ski **510** and a suspension and/or frame. The mount hole **126** may be a through hole or a blind hole. The mount holes **126** for the upper control arm mount **118**, lower control arm mount **122**, and tie rod mount **124** are configured to receive a fastener **150**, **152**, **154**. Optionally, one or more of the fasteners **150**, **152** and **154** are removably secured to the spindle **100**. In some embodiments, the upper control arm mount hole **126** is a blind hole, and the lower control arm and tie rod mount holes **126** are through holes (see e.g., FIGS. **10**A-C). The upper control arm mount hole **126** may define a threaded chamber configured to removably secure the fastener **150** to the upper control arm mount **118**. The chamber may include only a single opening for receiving the fastener, rather than a channel or tunnel through the body that is open at both ends. In some embodiments, the upper control arm mount hole **126** may be threaded by using a thread forming technique, whereby the threads are roll-formed. Such thread forming may densify and/or harden the threads and inner surface of the mount hole **126**, providing a strong connection point. In other embodiments, the upper control arm mount hole **126** may be threaded via a cutting thread. The mount hole **126** for the upper control arm mount **118** may be 30-50% of the volume of the upper control arm mount **118**—in other words 30-50% of the upper control arm mount **118** is hollow. In at least one embodiment, the fastener **150**, **152**, **154** has a head **156** and a body. In some embodiments, the fastener body includes a first body portion **158**, and a second body portion **160**. The first and second body portions **158**, **160** may have the same diameter or different diameters. In one example, the first body portion **158** has a greater diameter than the second body portion **160** (see e.g., FIG. **10**A). In another example, the fastener body tapers. In at least one embodiment, the first body portion **158** and/or second body portion **160** is threaded to mate with a threaded section of the mount wall (see e.g., FIGS. **10**B-C). In another example, the fastener **150**, **152**, **154** is press-fitted into the mount hole **126**. In another example, the lower portion of the fasteners **152** and **154** may be threaded and removably secured to the tie rod mount **124** and the lower control arm mount **122** with a threaded nut (not shown). In some embodiments, the upper control arm mount **118**, the lower control arm mount **122**, and the tie rod mount **124** each form a part of a ball joint. In some embodiments, the head **156** is positioned within a ball **157**, as illustrated for example, by fastener **150** (see e.g., FIGS. **10**A and **10**C). In other embodiments, the head **156** is a ball **157**, as illustrated for example, by fastener **152**.

In addition to a fastener **150**, **152**, **154**, the coupling of the spindle **100** to the front suspension **500** may further include a coupling housing or knuckle **507**. FIG. **15**A illustrates an example of an attachment assembly that may be utilized to couple the front suspension to the lower control arm mount **122**. The attachment assembly includes a knuckle **507** and a fastener **152**. In this example, the knuckle **507** includes a first portion **509** and a second portion **511**. The first portion **509** extends around a portion of a lower control arm **504**. The second portion **511** is positioned above the lower control arm mount **122** and extends at least partially around the shock **508**.

FIGS. **11**-**13**D include a perspective rear view, a front view, side views, and top views showing the attachment of two spindles **100** to a forward frame **540** of a snowmobile, according to some embodiments. The forward frame **540** may be a common forward frame—i.e. a frame that may be used for different snowmobiles. A steering column **512** may be coupled to the forward frame **540** by a steering column mount **520** that extends along the longitudinal axis **21** of the snowmobile. The steering column **512** includes a handle **542**. In some embodiments, the steering column **512** extends along line **25** and includes a second end operably connected to the forward frame **540** forward of at least a portion of the spindle **100** (see FIG. **12**A). In one example, the steering column **512** extends entirely over the top of the spindle **100** when viewed from the side of the forward frame **540** when the suspension is in a fully extended state and the skis are directed forward. In a non-limiting example, when viewed from the side of the forward frame **540** the second end of the steering column **512** is operably connected to the forward frame **540** at or forward of the lower control arm mount **122** when the suspension is in a fully extended state and the skis are directed forward.

In some embodiments, two spindles **100** are attached to the front suspension **500**. In these embodiments, the two spindles **100** are mirror images (see e.g., FIG. **11**). The exemplary forward frame **540** may be coupled to a front suspension **500**.

The front suspension **500** includes upper control arms **502** (e.g., A-arms), lower control arms **504** (e.g., A-arms), steering tie arms/rods **506**, shock absorbers **508**, and skis **510**. In some embodiments, the front suspension **500** is connected to the chassis by at least one bracket or fastener **550** (see e.g., FIG. **12**A). For example, the lower control arm **504** may be coupled to the forward frame **540** by a first bracket or casting **552** and by a second bracket or casting **553** (see e.g., FIGS. **11**B and **12**A).

The spindle is connected to the upper control arm **502** by the upper control arm mount **118**, to the lower A-arm **504** by the lower control arm mount **122**, to the steering tie rod/arm **506** by the tie rod mount **124**, and to the ski **510** by the ski mount **120**. A shock absorber **508** is also connected to the lower control arm mount **122** and/or lower A-arm **504** (see e.g., FIG. **11**B).

When the spindle **100** is attached to the ski **510**, the spindle **100** is oriented so that the bottom mount hole **126** is perpendicular to the long axis of the ski **510** (see e.g., FIGS. **12**B-C). In other words, the base longitudinal axis **146** of the base **119** is parallel to the long axis of the ski **510** and the long axis **13** of the ski mount **120** is perpendicular to the long axis of the ski **510**. In one aspect, a majority of the front suspension is positioned behind the ski mount **120** (see e.g., FIG. **12**D), when, for example, the suspension is in a fully extended state and the skis are directed forward. In some embodiments, windows **132** defined by the fin **128** are oriented substantially parallel to the long axis of the ski **510**. The window **132** may also be described as being oriented generally perpendicular to base longitudinal axis **146**. In other words, the window **132** is oriented perpendicular to a direction of forward travel so that a line through the window is perpendicular to the long axis of the ski **510** (see e.g., FIG. **12**C where a line through a window would go into the page). In other embodiments, the steering axis **140** is at an oblique angle to the ski **510** (see e.g., FIG. **12**D). In one example, the oblique angle is in the range of 25° to 35° and optionally 27° to 37°.

FIG. **16**A is a side view of a first embodiment of a snowmobile **600** with the suspension in a fully extended state and the skis directed forward, and FIG. **16**B is an enlarged view of the front portion of the snowmobile **600** of FIG. **16**A. FIG. **17**A is a side view of a second embodiment of a snowmobile **700** with the suspension in a fully extended state and the skis directed forward, and FIG. **17**B is an enlarged view of the front portion of the snowmobile **700** of FIG. **17**A. The track of each snowmobile **600**, **700** is removed for viewing purposes.

Each snowmobile **600**, **700** includes a skid frame assembly **602**, a common forward frame assembly **540**, a front suspension **620**, a belt housing assembly **630** operably connected to a track drive shaft, and an engine or motor assembly **640** operably connected to the belt housing assembly **630**. The belt housing assembly **630** may comprise the belt housing assembly disclosed in co-pending U.S. patent application Ser. No. 17/588,487 filed on Jan. 31, 2022 and titled "Adjustable Belt Drive Assembly, System and Method," the contents of which are incorporated by reference in its entirety. The skid frame assembly **602** supports an endless track (not shown) that is driven by the track drive shaft, and the skid frame assembly **602** includes one or more idler wheels **604**. As discussed above, the forward frame assembly **540** includes a steering column **512**. The forward frame assembly **540** may further include a front bumper **612**. The forward frame assembly **540** may be a common forward frame assembly utilized for different snowmobile embodiments, such as the two non-limiting examples illustrated in FIGS. **16**A and **17**A. As discussed above, the front suspension **620** is coupled to the forward frame **540** and includes a ski **510** and a spindle **100** with a ski mount **120**. The belt housing assembly **630** includes a top drive sprocket **632** and a bottom drive sprocket **634** that is operably connected to the track drive shaft. The engine or motor assembly **640** may include a recoil housing **642** and a crankshaft axis of rotation **643**. The position of a rider on the snowmobile **600** is approximated by a reference point **560** defining the uppermost fixed point on the steering column **512**.

Distances D**1**, D**2**, D**3**, D**4**, D**5**, H**1**, H**2**, H**3**, H**4**, H**5**, and H**6**, represent distances measured when the shocks are at full maximum length (i.e., full suspension). D**1**, D**2**, D**3**, D**4**, and D**5** are distances measured along the longitudinal axis **21** of the snowmobile **600**, **700** to the reference point **560**. H**1**, H**2**, H**3**, H**4**, H**5**, and H**6** are distances measured by a line perpendicular to the ground.

The centerpoint **605** of idler wheel **604** is positioned rearward of the centerpoint **635** of the bottom drive sprocket **634**. The centerpoint **635** is the location of the axis of rotation of the track drive shaft and may be referred to as such. The centerpoint **635** of the bottom drive sprocket **634** is positioned rearward of reference point **560** by a distance D**1**. The centerpoint **633** of the top drive sprocket **632** is positioned rearward of reference point **560** by a distance D**2**. The crankshaft axis of rotation **643** of the engine assembly **640** is positioned forward of reference point **560** by a distance D**3**. The centerpoint **121** of the ski mount **120** is positioned forward of reference point **560** by a distance D**4**. Distance D**4** may be shorter than for a typical snowmobile (such as an adult or full-size vehicle). A smaller value for distance D**4** positions the front suspension **620** and/or engine closer to the rider (a centralized mass) which may provide for a more responsive ride. The crankshaft axis of rotation **643** of the engine assembly **640** is positioned rearward of the centerpoint **121** of the ski mount **120** by a distance D**5**.

The centerpoint **635** of the bottom drive sprocket **634** is positioned rearward of the centerpoint **633** of the top drive sprocket **632** by a distance of D**1**−D**2**. The centerpoint **635** of the bottom drive sprocket **634** is positioned rearward the crankshaft axis of rotation **643** of the engine assembly **640** by a distance of D**1**+D**3**. The centerpoint **635** of the bottom drive sprocket **634** is positioned rearward of the centerpoint **121** of the ski mount **120** by a distance of D**1**+D**4**. The centerpoint **633** of the top drive sprocket **632** is positioned rearward of the crankshaft axis of rotation **643** of the engine assembly **640** by a distance of D**2**+D**3**. The centerpoint **633** of the top drive sprocket **632** is positioned rearward of the centerpoint **121** of the ski mount **120** by a distance of D**2**+D**4**. The crankshaft axis of rotation **643** of the engine assembly **640** is positioned rearward of the centerpoint **121** of the ski mount **120** by a distance of D**4**−D**3**.

The centerpoint **605** of a lower idler wheel **604** is positioned above the ground at a distance of H**1**. Reference point **560** is positioned above the ground at a distance of H**2**. The centerpoint **635** of a bottom drive sprocket **634** is positioned above the ground at a distance of H**3**. The centerpoint **633** of a top drive sprocket **632** is positioned above the ground at a distance of H**4**. The crankshaft axis of rotation **643** of the engine assembly **640** is positioned above the ground at a distance of H**5**. The centerpoint **121** of the ski mount **120** is positioned above the ground at a distance of H**6**.

In at least one embodiment, H**1**<H**6**<H**3**<H**5**<H**4**<H**2**. Thus, in at least one embodiment, the centerpoint **605** of idler wheel **604** is positioned closer to the ground than the centerpoint **121** of the ski mount **120**; the centerpoint **121** of the ski mount **120** is positioned closer to the ground than the centerpoint **635** of the bottom drive sprocket **634**; the centerpoint **635** of the bottom drive sprocket **634** is positioned closer to the ground than the crankshaft axis of rotation **643** of the engine assembly **640**; the crankshaft axis of rotation **643** of the engine assembly **640** is positioned closer to the ground than the centerpoint **633** of the top drive sprocket **632**; and the centerpoint **633** of the top drive sprocket **632** is positioned closer to the ground than reference point **560**.

In one example, H**1***a* is 10-25% of H**5***a*, optionally 15-20%; H**2***a* is 255-280% of H**5***a*, optionally 260-270%; H**3***a* is 75-85% of H**5***a*, optionally 78-82%, H**4***a* is 130-150% of H**5***a*; optionally 135-145%; H**6***a* is 15-30% of H**5***a*, optionally 20-25%; D**1***a* is 30-45% of H**5***a*, optionally 35-40%; D**2***a* is 5-15% of H**5***a*, optionally 8-13%; D**3***a* is 45-55% of H**5***a*, optionally 47-52% of H**5***a*; D**4***a* is 150-160% of H**5***a*, optionally 154-160%; and D**5***a* is 100-115% of H**5***a*, optionally 103-109%. (see e.g., FIG. **16**A). In an illustrative example, H**1** may be greater than H**6**.

In one example, H**1***b* is 10-25% of H**5***b*, optionally 15-20%; H**2***b* is 265-275% of H**5***b*; optionally 266-273%; H**3***b* is 75-85% of H**5***b*, optionally 78-82%; H**4***b* is 135-145% of H**5***b*, optionally 137-143%; H**6***b* is 15-30% of H**5***b*, optionally 20-25%; D**1***b* is 30-45% of H**5***b*, optionally 35-40%; D**2***b* is 5-15% of H**5***b*, optionally 8-13%; D**3***b* is 40-55% of H**5***b*, optionally 45-52%; D**4***b* is 155-170% of H**5***b*, optionally 157-163%; D**5***b* is 100-115% of H**5***b*, optionally 107-113% (see e.g., FIG. **17**A).

In one example, H**1** is 10-25% of H**5**, optionally 15-20%; H**2** is 255-280% of H**5**; optionally 260-273%; H**3** is 75-85% of H**5**, optionally 78-82%; H**4** is 130-150% of H**5**, optionally 135-145%; H**6** is 15-30% of H**5**, optionally 20-25%; D**1** is 30-45% of H**5**, optionally 35-40%; D**2** is 5-15% of H**5**, optionally 8-13%; D**3** is 40-55% of H**5**, optionally 45-52%; D**4** is 150-170% of H**5**, optionally 154-163%; D**5** is 100-115% of H**5**, optionally 103-113%.

One benefit of the common forward frame assembly **540** is that front suspension **620**, a belt housing assembly **630**, and an engine or motor assembly **640** utilized for different snowmobile embodiments may have different orientations, different sizes, and/or different positions. As noted above, one or more of the distances D**1**-D**5** and/or H**1**-H**6** may differ between snowmobile embodiments. For example, the crankshaft axis of rotation **643***a* may be positioned farther from reference point **560** than the crankshaft axis of rotation **643***b*—in other words D**3***b*<D**3***a*. This difference also results in a difference in the distance between the crankshaft axis of rotation **643** of the engine assembly **640** and the centerpoint of the top drive sprocket **632**—i.e., (D**2***b*+D**3***b*)<(D**2***a*+D**3***a*). As another example, the crankshaft axis of rotation **643***a* may be positioned higher above the ground than the crankshaft axis of rotation **643***b*—in other words H**5***b*<H**5***a*.

Other embodiments of the present disclosure are possible. Although the description above contains much specificity, these should not be construed as limiting the scope of the disclosure, but as merely providing illustrations of some of the presently preferred embodiments of this disclosure. It is also contemplated that various combinations or sub-combinations of the specific features and aspects of the embodiments may be made and still fall within the scope of this disclosure. It should be understood that various features and aspects of the disclosed embodiments can be combined with or substituted for one another in order to form various embodiments. Thus, it is intended that the scope of at least some of the present disclosure should not be limited by the particular disclosed embodiments described above.

Thus the scope of this disclosure should be determined by the appended claims and their legal equivalents. Therefore, it will be appreciated that the scope of the present disclosure fully encompasses other embodiments which may become obvious to those skilled in the art, and that the scope of the present 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." All structural, chemical, and functional equivalents to the elements of the above-described preferred embodiment that are known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the present claims. Moreover, it is not necessary for a device or method to address each and every problem sought to be solved by the present disclosure, for it to be encompassed by the present claims. 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.

The foregoing description of various preferred embodiments of the disclosure have been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure to the precise embodiments, and obviously many modifications and variations are possible in light of the above teaching. The example embodiments, as described above, were chosen and described in order to best explain the principles of the disclosure and its practical application to thereby enable others skilled in the art to best utilize the disclosure in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the disclosure be defined by the claims appended hereto.

Various examples have been described. These and other examples are within the scope of the following claims.

What is claimed is:

1. A spindle for a snow vehicle, the spindle comprising:

a base including a ski mount defining an axis of rotation;

an upper control arm mount securable to an upper control arm of the snow vehicle;

a lower control arm mount securable to a lower control arm of the snow vehicle;

a spindle body extending between the base, the lower control arm mount, and the upper control arm mount; and

a steering axis extending through the upper control arm mount, the lower control arm mount, and the ski mount,

wherein the steering axis extends along a vertical plane, wherein a centerpoint of the ski mount is positioned outboard of the vertical plane.

2. The spindle of claim **1**, wherein over 50% of the spindle body is positioned rearward of the steering axis.

3. The spindle of claim **1**, wherein the steering axis is oriented at a steering axis angle between 25° and 35° relative to a ground plane.

4. The spindle of claim **3**, wherein the spindle body includes a first portion extending between the base and the lower control arm mount, wherein an angle of the first portion relative to the ground plane is greater than the steering axis angle.

5. The spindle of claim **1**, further comprising:

a tie rod mount securable to a tie rod of the snow vehicle,

wherein a second vertical plane extending through the tie rod mount is positioned outboard from the centerpoint of the ski mount.

6. The spindle of claim **5**, wherein the spindle body includes a flat surface positioned outboard of the second vertical plane.

7. A spindle for a snow vehicle, the spindle comprising:

a lower control arm mount securable to a lower control arm of the snow vehicle;

an upper control arm mount securable to an upper control arm of the snow vehicle, the upper control arm mount positioned a first length from the lower control arm mount;

a tie rod mount securable to a tie rod of the snow vehicle, the tie rod mount positioned a second length from the lower control arm mount;

a base including a ski mount defining an axis of rotation, the base positioned a third length from the lower control arm mount; and

a spindle body extending between the base, the lower control arm mount, the tie rod mount, and the upper control arm mount,

wherein the tie rod mount is positioned outboard from the centerpoint of the ski mount.

8. The spindle of claim **7**, wherein the first length is less than the second length.

9. The spindle of claim **8**, wherein the third length is less than the first length.

10. The spindle of claim **9**, wherein a fourth length between the tie rod mount and the upper control arm mount is less than the third length.

11. The spindle of claim **7**, wherein the first length is between 50%-60% of a total spindle length between the tie rod mount and the ski mount.

12. The spindle of claim **7**, wherein the second length is between 60%-70% of a total spindle length between the tie rod mount and the ski mount.

13. The spindle of claim **7**, wherein the third length is between 30%-40% of a total spindle length between the tie rod mount and the ski mount.

14. A spindle for a snow vehicle, the spindle comprising:

a lower control arm mount securable to a lower control arm of the snow vehicle;

an upper control arm mount securable to an upper control arm of the snow vehicle, the upper control arm mount positioned a first height from the lower control arm mount;

a tie rod mount securable to a tie rod of the snow vehicle, the tie rod mount positioned a third height from the lower control arm mount;

a base including a ski mount defining an axis of rotation, the base positioned a second height from the lower control arm mount; and

a spindle body extending between the base, the lower control arm mount, the tie rod mount, and the upper control arm mount,

wherein the tie rod mount is positioned outboard from the centerpoint of the ski mount.

15. The spindle of claim **14**, wherein the first height is greater than the second height and the second height is greater than the third height.

16. The spindle of claim **15**, wherein a fourth height between the upper control arm mount and the tie rod mount is greater than the second height.

17. The spindle of claim **14**, wherein the first height is between 55%-65% of a total spindle height between the upper control arm mount and the ski mount.

18. The spindle of claim **14**, wherein the second height is between 35%-45% of a total spindle height between the upper control arm mount and the ski mount.

19. The spindle of claim **14**, wherein the third height is between 5%-10% of a total spindle height between the upper control arm mount and the ski mount.

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