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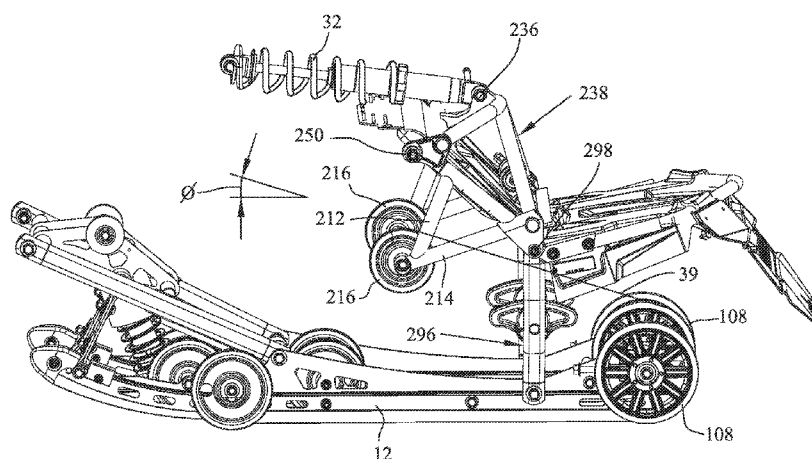


FIG. 27

(57) Abstract: A snowmobile rear suspension is shown comprised of a linear force element (LFE) positioned outside the envelope of the snowmobile endless track. The LFE is attached at one end to the frame and at the other end to a bell crank. The bell crank is operatively connected to the slide rails, and carrier rollers extend from the bell crank. When the slide rails collapse in normal operation, the bell crank strokes the LFE, and the suspension is progressive throughout the range.

SNOWMOBILE AND REAR SUSPENSION FOR SNOWMOBILE

Background of the Invention

[0001] The present invention relates to suspension systems for snowmobiles, and more particularly, the present invention relates to snowmobile rear suspensions. In an illustrated embodiment, progressive rate rear suspension architecture for snowmobiles is disclosed.

[0002] Performance characteristics of snowmobiles, including the comfort of the ride, depend on a variety of systems and components, including the snowmobile suspension. Typically, a snowmobile suspension includes two systems, a front suspension system for a pair of skis and a rear suspension system for the track.

[0003] The rear suspension of a snowmobile supports an endless track driven by the snowmobile engine to propel the machine. The track is supported beneath a vehicle chassis by a suspension that is designed to provide a comfortable ride and to help absorb the shock of the snowmobile crossing uneven terrain. Most modern snowmobiles use a slide rail suspension which incorporates a pair of slide rails along with several idler wheels to support the track in its configuration. The slide rails are typically suspended beneath the chassis by a pair of suspension arms, with each arm being attached at its upper end to the chassis of the snowmobile, and at its lower end to the slide rails. The mechanical linkage of the slide rails to the suspension arms and to the snowmobile chassis typically is provided by springs and at least one element acting along a linear path, such as a shock absorber, damper, air shock, shock and spring combination, or other linear force element (LFE). The springs are loaded to bias the slide rails downwardly away from the snowmobile chassis and the shock absorbers; dampers or LFEs provide damping forces for ride comfort.

[0004] There are presently two general types of snowmobile rear suspensions in all of the snowmobile industry: coupled and uncoupled. The term "coupled" is given to

suspensions that have dependant kinematics front-to-rear and/or rear-to-front (relative to the rear suspension rail beam). That is, a suspension is coupled “front-to-rear” when the front of the suspension is deflected vertically and the rear also moves vertically to some degree. A suspension is coupled “rear-to-front” when the rear of the suspension is deflected vertically and the front also moves vertically to some degree. A suspension is considered to be coupled “tighter” front-to-rear, or increased coupling bias to the front, if a front deflection causes near the same rear deflection. The same is true if a suspension is coupled “tighter” rear-to-front, or increased coupling bias to the rear: a rear deflection causes near the same front deflection. An uncoupled rear suspension functions independently front-to-rear and rear-to-front. A deflection of the front portion of the suspension causes little to no deflection of the rear portion and vice versa.

[0005] There are two main advantages to a coupled suspension. First, a coupled suspension shares rate when coupled. There is a distinct rate associated with the front of the suspension and a separate distinct rate associated with the rear of the suspension; when a suspension “couples” it borrows the rate of both the front and rear of the suspension so the overall rate becomes higher than could have been achieved without coupling. Second, coupling is used to control weight transfer during acceleration. An uncoupled suspension will allow excessive chassis pitch due to the independence of the suspension. Coupling stops this by limiting the angle of the slide rail and by increasing the rate of the suspension and “locking” the suspension geometry.

[0006] Typically the use of a coupled suspension, uncoupled suspension, and the degree to which a suspension is coupled depends on the expected use. Coupled suspensions are mostly used on trail/performance snowmobiles where large bumps and tight corners require increased rate and controllable weight transfer. Uncoupled suspensions are used on deep snow/long track snowmobiles where weight transfer and traction are more important.

[0007] There are many ways to create a coupled rear suspension. The simplest form of a rear suspension is a four-link suspension created by the chassis, two arms,

and the slide rails all connected with rotational pivots. This type of suspension yields only one degree of freedom. The slide rail motion and suspension kinematics are predefined by the length of the 4 links and cannot be altered due to the location of the input (front, rear, or between). This is not desirable because the slide rail will not follow undulating terrain or allow any angle change relative to the chassis due to acceleration. To fix this problem with a basic four-link, one of the links is allowed to change length to some degree. The geometry of the four-link therefore changes relative to the location of the input. A deflection of the front portion of the suspension yields one distinct four-link geometry and a deflection of the rear portion of the suspension yields different distinct four-link geometry. There is always some degree of uncoupled behavior in a coupled suspension when the geometry is not locked front-to-rear or rear-to-front. It is important to note that most coupling is focused on rear-to-front to help control excessive weight transfer. The majority of differences in rear suspension architecture are driven by accomplishing this same goal of a “sloppy” four-link in different ways.

[0008] Figure 1 illustrates an example of a traditional rear suspension 10 (illustratively a 2D model of the Polaris Fusion[®] snowmobile rear suspension design) having slide rails 12, a front suspension arm 14 and a rear suspension arm 16. Front suspension arm 14 is coupled to the slide rails 12 by pivot connection 18. An opposite end of front suspension arm 14 is pivotably coupled to the chassis. Rear suspension arm 16 is pivotably coupled to the slide rails 12 by pivot connection 20. An opposite end of the rear suspension arm 16 is pivotably coupled to the chassis. Torsion springs are illustratively mounted between the rear torque arm and slide rails 12. First and second linear force elements (LFE) 22 and 24 are coupled between the first and second suspension arms 14 and 16, respectively and the slide rails 12 in a conventional manner.

[0009] Figure 1 labels the following geometry of a four bar link which is similar in most snowmobile rear suspensions as illustrated by the lines defining: A) Front Link, B) Rear Link, C) Rail Link, and D) Chassis Link. These links and their relative lengths govern the majority of rear suspension kinematics.

[0010] The coupling bias behavior as described above is dependant on this four-link geometry and is important to rear suspension rate, impact harshness, and ride quality. For example, a perfectly symmetric four-link ($A=B$ and $C=D$, A parallel to B and C parallel to D) will yield a rail angle that is maintained at the same angle throughout travel. In other words, the rail 12 does not rotate relative to the chassis as the suspension is compressed. This type of movement is not desirable due to the need to achieve traction on undulating terrain. As deviations to this symmetric geometry are made, the rail angle will change throughout suspension travel.

[0011] As traditional suspensions are compressed, the front arm begins to “point” at the rear arm mount location. This is known as “over centering”. Figures 2 and 3 illustrate this graphically, showing how links A and C have become substantially a straight line.

[0012] A rear suspension that is coupled rear-to-front has the same over-centering problems as discussed above for a front load situation, but to a larger degree. Figure 4 illustrates this problem graphically when a rear load is applied as illustrated by arrow 27, showing how link B has crossed over link C. As mentioned above, over-centering drastically reduces effective suspension rate and damper velocities.

[0013] The problem lies in packaging a four link geometry that does not move over-center during compression. Consider another common four-link suspension, the SLA (Short-Long Arm) suspension. Figure 5 illustrates a common snowmobile SLA front suspension 30 with labels equivalent to Figure 1 for links A, B, C and D. Details of the SLA front suspension are described in U.S. Patent No. 6,942,050 which is incorporated herein by reference. This arrangement does not move over-center upon compression due the placement of chassis mount points of A and B at locations 17 and 19, respectively, in Figure 5. The vertical separation is a high percentage of link D. Therefore, the first factor in eliminating over-centering in rear suspensions is to place the rear arm significantly higher than the front arm as outlined in the above discussion about coupling behavior.

[0014] Simply moving the rear point of a conventional suspension upward is not feasible. The rear arm needs to become significantly shorter than the front. Typical link ratios (A/B) on conventional suspensions are between 1 to 1.5. Ratios other than this are not feasible or do not package in current design envelopes. However, to accommodate a higher rear mount, A/B ratios need to increase to the range of about 1.6 to 2.0. Therefore, in an illustrated embodiment, A/B ratios are preferably 1.6 to 2.0 or greater in coupled suspensions. Figure 6 illustrates the difference in a rear load case coupling angle between a conventional suspension labeled as "Prior Art" (illustratively the Polaris IQ 440 suspension) and the illustrated embodiment described below (labeled as "Improved Rear Suspension Coupled" and "Improved Rear Suspension Uncoupled").

[0015] Figure 7 illustrates the difference in the coupling angle between a conventional suspension and the suspension of the present improved suspension invention described below. Conventional suspensions yield a front coupling angle that increases through travel. This means that as the conventional suspension is compressed, the angle of the slide rail increases. This type of behavior is not ideal because as the rail angle increases, rate and damper velocities decrease ultimately resulting in a regressive suspension. More desirable is a rail angle that decreases as the suspension is compressed; thus, effectively making the suspension rate progressive (the more regressive the rail angle, the more progressive the rate). However, an increasing coupling angle is difficult to eliminate due to the packaging of a traditional snowmobile suspension. In the illustrated embodiment of the present invention, unconventional packaging of the suspension components results in a vertical difference between the front arm and rear arm chassis mounts of preferably 20% or more of the chassis link length (D) which results in a decreasing coupling angle.

[0016] Further examination of coupling behavior yields two constraints necessary to maintain reasonable component loads and basic function of the rail/ground interface. First, this angle should be positive. In other words, when a load is applied to the front of the suspension as illustrated by arrow 25 in Figure 3, the front portion of the slide rails 12 moves more than the rear portion and vice versa for a load applied to the rear of the

suspension. Second, there should be no inflections, or change in sign of the slope, in the curve of rail angle versus vertical deflection, as shown in Figures 6 and 7. In other words, when a load is applied to the front of the suspension, at no point should the rear of the suspension begin to move faster than the front and vice versa for a load applied to the rear of the suspension.

[0017] Because an uncoupled suspension does not form a distinct four-link, no over-centering can occur. No link ratio is then necessary for a rear load case in an uncoupled suspension. This is very beneficial, but excessive vehicle pitch and lack of vertical rate usually make uncoupled suspensions behave poorly for load carrying capacity and ride quality. Typically, for these suspensions a link ratio is then tuned only for the front load case. The shock/spring ratio can be tuned to help counteract the deficiencies of an uncoupled suspension. In this way, the rear arm geometry is tuned exclusively to maximize rear load case rate. Therefore, linkage arm length ratios are tuned for front coupling and rear rate in uncoupled suspensions.

[0018] As discussed above, the majority of snowmobile rear suspension architectures utilize a combination of springs, dampers, or other similar linear force elements (LFE), all packaged within the envelope of the track. Regardless of how these elements are packaged, these designs typically use two methods to generate vertical rate: 1) the LFE is located so that there is some vertical component reacted between the suspension arm and rail beam, and 2) the LFE is connected to the suspension arm such that a torque reaction is generated about the upper pivot. The inherent problem is that these designs lose rate near full jounce due to the suspension mechanism components becoming generally planar. That is, all the suspension components fold down until they are lying relatively flat as the suspension components move at full jounce. This is due to the large vertical travel requirements of a snowmobile suspension.

[0019] The result of the suspension components becoming planar is that the load vector of the LFEs begins to point horizontally instead of vertically. This transfers load

into the internal components of the suspension and does not react vertically to suspend the vehicle. Also, as the suspension components become planar, the moment arm through which the suspension reacts increases at a faster rate than can be controlled by the shock/spring ratio, regardless of the type of linkage used to accelerate the shock/spring.

[0020] With reference again to Figures 1 and 2, Figure 1 shows a 2D representation of suspension 10 at full rebound. Figure 2 shows suspension 10 at full jounce. The front and rear LFEs 22, 24 become generally planar and lay down and point nearly horizontally in Figure 2. The rear torque arms get “longer” measured from the upper pivot to lower pivot in the horizontal direction. Even with a complicated linkage to help stroke the rear LFE 24, a progressive rate cannot be maintained due to the two reasons listed above. This is true for all conventional snowmobile rear suspension systems.

[0021] Load at the slide rails and, more importantly, the bias between front and rear load is directly related to coupling, especially for a front load case. Consider the traditional suspension as illustrated in Figure 1. The architecture is such that the front spring/damper 22 acts between the front arm 14 and the slide rail 12, and both the torsion springs and rear damper 24 act between the rear arm 16 and the slide rail 12 near the front. Therefore, during a front load case, both springs and dampers 22, 24 have a large effect on load and rate. The same is true of a rear load case. Attempting to tune the front LFE 22 will change the load/rate at the front and rear, and vice versa. Also if the coupling were increased, the rail angle decreases through travel and the rate will increase. In order to tune the suspension rate, the front LFE 22, rear LFE 24 and torsion springs, and coupling angle all need to be adjusted.

[0022] To improve this system: 1) Front coupling can be used primarily to control front load/rate, 2) Front preload is adjusted by a small LFE near the front of the rail (has a very small affect on rate), and 3) rear preload and rate is determined by the rear arm only. To achieve this with actual architecture, the main rear LFE needs to react only at

the rear arm and with no other suspension components. Therefore reacting the LFE on the chassis in the above discussion is important not only for progressive rate, but also for load bias. When these three conditions are true, rear coupling does not greatly influence rate. This is realized because the front LFE is only used for preload so there is generally very little rate to “borrow” from the front of the rail during a rear load case.

[0023] Progressive rate suspensions have not yet been achieved in snowmobile rear suspension designs because 1) the vertical component of the LFE becomes very small as the LFEs become horizontal and planar with the suspension during jounce, and 2) the rotational component of the LFE about the arm pivot also cannot increase faster than the increase in arm length moment.

[0024] The state of snowmobile rear suspensions in the industry consists entirely of falling rate, or regressive suspension designs. Even though there is a large variety in the suspension architecture from one manufacture to another, commercially available designs yield an overall suspension stiffness that decreases as the suspension is compressed toward full jounce. Some architectures yield discontinuities that may locally spike the rate for a short time (such as an overload spring), but afterwards the rate continues to decrease. Because most design effort is directed at optimizing a damper or spring motion ratio instead of analyzing the entire suspension system there are currently no progressive rate suspensions in the industry.

[0025] Now with regard to chassis construction, traditional snowmobile chassis structures consist of elements common to each manufacturer, especially in the tunnel and rear suspension portion of the snowmobile. Typically, the rear suspension includes two suspension arms attached to the chassis tunnel frame and a drive shaft mounted forward of the front arm to drive the endless track.

[0026] This conventional suspension arrangement poses two problems. First, track tension through suspension travel relies on the relative placement of the suspension arms and wheels to the drive shaft. Suspension mount locations are often

determined not only by specific, desired suspension characteristics, but also on track tension packaging. Problems are encountered from both an over and under tensioning track standpoint. Second, the front arm placement is limited to remain outside the drive sprocket diameter due to interference with drive train components. This creates problems when attempting to change the weight transfer behavior of the rear suspension, which is dominated by front arm mount location.

[0027] Achieving the mount points for desirable rate and kinematics is only half the challenge of snowmobile suspension design. Packaging a track around the suspension is the other. Traditional suspensions sacrifice more optimum suspension geometry to provide track tensioning and packaging which can be extremely difficult to manage.

[0028] All of these problems are solved by mounting the front swing arm coaxial with the drive shaft as discussed below. Because the front swing arm rotates around the same axis as the track drive sprocket, track tension is only influenced by the slide rail approach bend profile and a rear suspension idler pulley. Also, the coaxial placement of the arm creates improved weight transfer behavior of the rear suspension.

[0029] In order to generate necessary traction under acceleration, weight transfer and pitch need to be considered. Suspension parameters are tuned to facilitate the shift of vehicle weight from the skis to the track. This shift in weight is imperative for snowmobile acceleration due to slippery ground conditions. There are many parameters, but the two that dominate are front arm mount locations and carrier wheel.

[0030] Vehicle pitch is partially a result of this weight shift, but excessive pitch can result without increased traction. Packaging constraints, such as track carrier wheels, within the design of the suspension may limit or increase the ability of the vehicle to pitch.

[0031] With this design, the improved suspension may eliminate the carrier wheel. This changes the load vector into the suspension from the track due to tractive

forces between the track and ground. In the illustrated embodiment, the load vector from the track is more horizontal which induces less pitch and weight transfer than a traditional suspension. To improve this, the front arm is moved significantly forward to facilitate weight transfer. This point can move forward incrementally until it encounters the drive wheel inscribed circle. At this point, it can only move coaxial with the drive sprocket. The illustrated embodiment of the present invention utilizes a coaxial front arm mount as discussed herein to facilitate weight transfer and pitch.

[0032] As for the frame assemblies, traditional snowmobiles utilize a long tunnel structure to which the driveshaft and rear suspension mounts beneath. Above the tunnel typically sits a fuel tank and seat. This type of structure is adequate because most spring/damper forces are reacted internal to the suspension and between the front and rear arm mounts. Additional structure to the base tunnel is only required between these mounts.

[0033] PCT publication Number WO/2007/100751 discloses a snowmobile rear suspension comprised of a linear force element (LFE) positioned outside the envelope of the snowmobile endless track. The LFE is attached at one end to the frame and at the other end to a bell crank. The bell crank is operatively connected to the slide rails.

Summary of the Invention

[0034] The embodiments disclosed herein provide a snowmobile comprising a frame; endless track for driving the snowmobile; slide rails for mounting the endless track; at least one linkage between the slide rails and frame, the linkage comprising a pivot link, where the pivot link pivots in response to movement between the slide rails and the frame. At least one linear force element (LFE) is positioned between the linkage and the frame, whereby pivotal movement of the linkage strokes the LFE. The carrier rollers are coupled to the at least one linkage, with the endless track positioned over the carrier rollers.

[0035] In another embodiment, a snowmobile comprises a frame; endless track for driving the snowmobile; slide rails for mounting endless track; at least one linkage between the slide rails and frame, with a portion of the linkage being positioned below the endless track and a portion of the linkage positioned above the endless track; and at least one linear force element (LFE) positioned substantially horizontally, with one end attached to the frame and one end connected to the at least one linkage. A track tensioner is coupled to the portion of the linkage positioned above the endless track with the endless track positioned against the track tensioner.

[0036] In yet another embodiment, a snowmobile comprises a frame; slide rails coupled to the frame; endless track mounted to the slide rails; a suspension assembly coupling the slide rails to the frame; at least one linear force element (LFE) positioned outside of the envelope defined by the endless track, one end of the LFE being attached to the frame and the opposite end being attached to the suspension assembly. Carrier rollers are coupled to the suspension assembly, with the endless track passing through the suspension assembly and over the carrier rollers.

Brief Description of the Drawings

[0037] Embodiments of the present snowmobile will now be discussed with reference to the drawings, where:

[0038] Figure 1 shows a diagrammatical view of a conventional snowmobile suspension system in full rebound;

[0039] Figure 2 shows a diagrammatical view of a conventional snowmobile suspension system in full jounce;

[0040] Figure 3 shows the diagrammatical view of a conventional snowmobile suspension system according to Figure 1 and 2, with a front load applied;

[0041] Figure 4 shows the diagrammatical view of a conventional snowmobile suspension system according to Figure 1 and 2, with a rear load applied

[0042] Figure 5 shows a diagrammatical view of a conventional snowmobile front suspension system;

[0043] Figure 6 shows a comparison curve of the prior art versus the improved suspend with a rear load;

[0044] Figure 7 shows a comparison curve of the prior art versus the improved suspend with a front load;

[0045] Figure 8 shows a diagrammatical perspective view of the suspension of the present invention;

[0046] Figure 9 shows a diagrammatical plan view of the suspension of Figure 8;

[0047] Figure 10 shows a diagrammatical plan view of the suspension of the present invention at full rebound;

[0048] Figure 11 shows a diagrammatical plan view of the suspension of the present invention at full jounce;

[0049] Figure 12 shows a diagrammatical perspective view of an alternate suspension;

[0050] Figure 13 shows a diagrammatical plan view of the suspension of the present invention retro-fit on an existing suspension;

[0051] Figure 14 shows a diagrammatical plan view of another suspension of the present invention retro-fit on an existing suspension;

[0052] Figure 15 shows a perspective view of the suspension of the present invention applied to a tunnel and to slide rails;

[0053] Figure 16 shows a perspective view of the suspension of Figure 16, with the chassis and tunnel removed;

- [0054]** Figure 17 shows a plan view of the Figure 16 embodiment;
- [0055]** Figure 18 shows an enlarged perspective view of Figure 16, showing the front suspension mounts;
- [0056]** Figure 19 shows an enlarged view of the connection of the front suspension mounts of Figure 18 to the slide rails;
- [0057]** Figure 20 shows a partial sectional view of one driveshaft assembly;
- [0058]** Figure 21 shows the driveshaft assembly of Figure 20, partially disassembled;
- [0059]** Figure 22 shows a partial sectional view of another possible driveshaft assembly;
- [0060]** Figure 23 shows the driveshaft assembly of Figure 22, partially disassembled;
- [0061]** Figure 24 shows an enlarged perspective view of Figure 16, showing the rear suspension mounts to the slide rails;
- [0062]** Figure 25 shows an enlarged perspective view showing the pivotal sliding coupling connection of the rear suspension mounts to the slide rails; and
- [0063]** Figures 26 and 27 show an additional rear suspension embodiment of the present invention.

Detailed Description of Embodiments of the Invention

[0064] Features and advantages of the present invention will become apparent to those skilled in the art upon consideration of the following detailed description of illustrative embodiments exemplifying the best mode of carrying out the invention as presently perceived.

[0065] The embodiments disclosed below are not intended to be exhaustive or to limit the invention to the precise forms disclosed in the following detailed description. Rather, the embodiments are chosen and described so that others skilled in the art may utilize their teachings.

[0066] A progressive rear suspension is disclosed for a rear suspension system of a snowmobile. A progressive suspension is one having a stiffness that increases throughout (or at least substantially throughout) the entire range of suspension travel.

[0067] A diagrammatical depiction of the progressive suspension is shown in Figures 8-14, and will be described representatively. This progressive suspension provides improved ride with less bottoming and better energy dissipation.

[0068] With reference first to Figures 8 and 9, an illustrated embodiment of a suspension 30 of the present invention is shown. Suspension 30 includes a pair of slide rails 12, and a swing arm 31 having a first end coupled to slide rails 12 at location 33 and a second end 35 pivotably coupled to the chassis. A frame 41 (Figure 9) is configured to define a tunnel 40 which receives the track 39 therein. In the illustrated embodiment, the main LFE 32 is located generally horizontally above the tunnel 40 with one end connected to the chassis at location 34 and the other end 36 connected to a bell crank 38 that redirects the load vertically. A second LFE 37 includes a first end 43 which is pivotably coupled to the slide rails 12. A second end 45 of LFE 37 is pivotably coupled to link 47. As shown in Figure 8, an opposite end of link 47 is pivotably coupled to swing arm 31 by connector 49. As discussed below bell crank 38 generally forms a triangular shape with corner 50 coupled to the chassis, corner 52 coupled to end 36 of LFE 32, and corner 54 coupled to end 45 of LFE 37.

[0069] It is understood that the actual architecture of the rest of the suspension 30 may vary from what is shown in Figures 8 and 9. Many prior art suspensions may also benefit from this design by connecting the horizontal LFE 32 to any of the suspension arms through a bell crank 38. The bell crank 32 redirects the shock load

vertically. By changing the length and angles between the input and output arms of the bell crank 38, a progressive rate can be achieved for virtually any suspension design.

[0070] As discussed above, the main LFE 32 is illustratively placed outside the envelope defined by track 39 and above the tunnel 40 as shown in Figure 9. One end 34 of the LFE 32 is connected to the chassis and the other end 36 is connected to an end of a bell crank 38. The other end of the bell crank 38 is connected to the suspension components, either through a link, pivot, slider, or other suitable connection. The suspension components extend around the track 39 in order to connect components located within the envelope of the track 39 to the LFE 32. Details of an illustrated embodiment of this connection are described below.

[0071] As shown in Figure 9, one such improved suspension places at least one LFE outside the envelope defined by the track and above the chassis tunnel. One end of the LFE is connected to the chassis and the other end is connected to an end of a bell crank. The other end of the bell crank is connected to the suspension components, either through a link, pivot, slider, or other suitable connection. As the suspension compresses into jounce, the suspension end of the bell crank moves vertically some amount which causes the crank to rotate. This, in turn, causes the LFE end of the bell crank to move horizontally and stroke the LFE. This is what provides the vertical suspension rate.

[0072] Comparing an example of the improved suspension at full rebound (Figure 10) to full jounce (Figure 11), it is shown that the horizontal distance from the crank pivot to the crank suspension end increases. This increase of the “output” bell crank moment arm by itself would make the vertical load decrease through travel. However, the vertical distance between the crank pivot and the crank LFE end increases. This increase in the “input” bell crank moment arm balances the increase in the “output” and maintains the vertical load. By changing the relative length of the arms and the angles between them, a progressive rate can be generated for most suspension load cases.

[0073] The arm lengths and angles of the bell crank 38 are important to the operation of the suspension 30. Figures 10 and 11 show the illustrated embodiment at full rebound and at full jounce, respectively. The large triangle represents the bell crank 38. The left corner of the triangle 50 below the LFE 32 is the pivot connector to the chassis. The top most corner 52 is connected to the LFE 32, and the bottom most corner 54 is connected to the suspension (in this case through the link 47). Comparing the suspension 30 at full rebound (Figure 10) to full jounce (Figure 11), it is shown that the horizontal distance from the crank pivot to the crank suspension end increases. This increase of the “output” bell crank moment arm by itself would make the vertical load decrease through travel. However, the vertical distance between the crank pivot and the crank LFE end increases. This increase in the “input” bell crank moment arm balances the increase in the “output” and maintains the vertical load. By changing the relative length of the arms and the angles between them, a progressive rate can be generated for most suspension load cases.

[0074] Another illustrated embodiment uses two bell cranks 42, 44 which connect to the suspension at two points so an LFE 46 is actuated from both ends as shown in Figure 12. In this illustrated embodiment, the LFE 46 may be placed front-to-back or left-to-right above the tunnel 40. Figure 12 shows a design with the LFE 46 placed left-to-right between bell cranks 42, 44.

[0075] As stated above, the present invention may also be applied to existing rear suspensions, and Figures 13 and 14 show a retro-fit to the Polaris Fusion® rear suspension shown in Figures 1-3. Figure 13 discloses use of a single bell crank 38 coupled between rear suspension arm 16 and LFE 32. Figure 14 discloses use of dual bell cranks 38 and 38'. In Figure 14, a first end of bell crank 38 is coupled to end 36 of LFE 32 and a second end of bell crank 38 is coupled to rear suspension arm 16 by link 51. A second bell crank 38' has a first end coupled to end 34 of LFE 32 and a second end coupled to front suspension arm 14 by link 51'.

[0076] Operation of only one illustrated suspension architecture will be discussed since the general operation is the same regardless of where the suspension end of the bell crank 38 is connected. As the suspension compresses into jounce, the suspension end of the bell crank 38 moves vertically some amount which causes the crank 38 to rotate. This, in turn, causes the LFE end of the bell crank 38 to move horizontally and stroke the LFE. This is what provides the vertical suspension rate.

[0077] With reference now to Figures 15-25, a complete depiction of one embodiment of the rear suspension 60 of the present invention will be described. Those elements referenced by reference numbers identical to the numbers above perform the same or similar function.

[0078] With reference first to Figure 15-17, rear suspension 60 is shown attached to tunnel 40, and illustrates the suspension 60 coupled to a frame 41 which defines the tunnel 40 for track 39 (Figures 16-17). This system is generally comprised of, slide rails 12, LFE 32, bell crank 38, tunnel 40, chassis 70, front swing arms 80 and an A-shaped pivot member 96. More particularly, LFE 32 is shown suspended between bell crank 38 and a chassis structure 70. Bell crank 38 is attached to A-shaped pivot member 96, which in turn is attached to slide rails 12. Figure 17 shows that the main LFE 32 is located horizontally above the frame 41 which defines the tunnel 40.

[0079] In the embodiment of Figures 15-17, and as best shown in Figures 16 and 17, a front swing arm 80 is pivotably coupled to the slide rails 12 by a pivot connection 82 as discussed in further detail below. An opposite end 84 of swing arm 80 is pivotably coupled to the chassis about which a drive mechanism 85 is attached, having an axis which is coaxial with a drive shaft 86 as also discussed in detail below. With reference first to Figures 18 and 19, the connection of the front swing arm 80 to slide rail 12 will be described.

[0080] Traditional suspensions typically mount the front and rear control arms to the slide rails in one of two methods: 1) Pivot shaft extends between beams and

passes through a pivot tube on the arm, or 2) A left and right pivot shaft is mounted to the beams and each pass through a small pivot tube on the arm. Although both designs are relatively simple and have worked well in current designs, there are several problems with both.

[0081] The long pivot shaft works well to distribute suspension loads across a large area on the pivot shaft. However, maintaining lubrication is difficult and high bending loads can be present thus requiring a large through fastener. The short left/right pivot design can be used with small self lubricated bushings, but the cantilevered load also requires a large fastener.

[0082] A clevis joint design as shown in Figure 19 solves the deficiencies of each of the above designs. The size of the joint makes it possible to use small lubricated bushings and because the clevis “straddles” the rail beam, no bending load is present in the fastener so smaller fasteners may be used with equivalent durability. In this design, the clevis portion of the joint is part of the control arm.

[0083] Clevis connection 82 is provided between the swing arm 80 suspension components and slide rail 12 as shown in Figure 19. Ends 112 of swing arm 80 each include a slot 114 which receives a portion 116 of slide rails 12 therein. Bolts 118 then secure the ends 112 to portions 116 of the slide rails 12.

[0084] With respect again to Figure 18, the front drive mechanism 85 will be described in greater detail. Drive shaft 86 rotates a plurality of drive sprockets 88 which have a plurality of teeth to engage and move the track 39 in a conventional manner. A pre-load spring 90 has a first end 92 pivotably coupled to swing arm 80 and a second end 93 pivotably coupled to slide rails 12 at pivot connection 94.

[0085] As mentioned above, conventional suspension arrangements pose two problems. First, track tension through suspension travel relies on the relative placement of the suspension arms and wheels to the drive shaft. Suspension mount locations are often determined not only by specific, desired suspension characteristics, but on track

tension packaging. Problems are encountered from both an over and under tensioning track standpoint. Second, the front arm placement is limited to remain outside the drive sprocket diameter due to interference with drive train components. This creates problems when attempting to change the weight transfer behavior of the rear suspension, which is dominated by front arm mount location.

[0086] Both of these problems are solved by mounting the front swing arm 80 coaxial with the drive shaft 86 as discussed above and shown in detail in Figure 18. Because the front swing arm 80 rotates around the same axis as the track drive sprocket 88, track tension is only influenced by the slide rail 12 approach bend profile and the rear suspension idler pulley 108. Also, the coaxial placement of the arm 80 creates improved weight transfer behavior of the rear suspension 60.

[0087] There are two illustrated arrangements in which the arm 80 is mounted coaxial to the drive shaft 86 either on the drive shaft 86 or the chassis. Figure 18 shows the first arrangement where the arm 80 is mounted directly to the drive shaft 86. In this arrangement, bearings are used in the connection to allow the drive shaft 86 to rotate within the ends 84 of the suspension arm 80. The advantages of this connection are twofold, lateral packaging of the arm 80 in the chassis tunnel is easier, and the arm strengthens the drive shaft 86. In this embodiment, however, high speed bearings are required at this connection, and the drive shaft 86 must now react to suspension loads.

[0088] The second arrangement for mounting the swing arm 80 is to use larger hollow connections between the suspension arm and the chassis. The drive shaft 86 then passes through this connection. In the illustrated embodiment, a quick change drive shaft assembly is designed to be easily removed from a chassis. This provides improved serviceability and maintenance, and improved assembly procedure.

[0089] Traditional snowmobiles have typically used drive shafts that are wider than the tunnel. This is to simplify the number of parts in the assembly and still allow mounting to each edge of the tunnel with a single shaft. However, this makes assembly

and service difficult. In order to remove the drive shaft you need to open the chain case, loosen the drive shaft bolt, slide the drive shaft out of the chain case, twist the drive shaft and remove it from the tunnel. Sliding the drive shaft and twisting to the side can be very difficult due to the tunnel/track clearance.

[0090] The illustrated embodiment provides two designs that make this process easier. The first design consists of a two part drive shaft assembly: an inner shaft and outer sleeve. The second consists of a removable spline stub that couples the shaft to the chain case.

[0091] This first sleeve embodiment is depicted in Figures 20 and 21, and includes a drive shaft similar to current designs, but the drive sprockets 88 are mounted to an outer sleeve 180 (instead of the shaft directly) that is slightly narrower than the tunnel 40. The two parts are then torsionally coupled through either sliding splines, hexes, or other similar fit. The inner shaft 182 is tightly mounted to the chain case 184 by means of a fastener and the outer sleeve 180 is compressed when the inner shaft 182 is tightened from the end opposite the chain case 184.

[0092] To assemble this design, and as best shown in Figure 21, the sleeve 180 is placed in the tunnel and the shaft 182 slides completely through the sleeve 180, from the outside of the tunnel, into the chain case 184. The shaft 182 is torsionally coupled to the drive mechanism inside the chain case and fastened solidly with a screw 186. The chain case 184 has an access opening 187 to install the screw 186 so the case 184 does not need to be opened to access the drive shaft 182. The entire assembly is clamped tight from the side opposite the chain case 184. As this is tightened, the outer sleeve 180 is compressed from each end by the main drive shaft bearings.

[0093] Alternatively, a drive shaft according to Figures 22 and 23 could be used, where a spline stub for coupling to the chain case 184 is female instead of male. This allows the overall length of the shaft 188 and the amount of shaft protruding inside the

chain case 184 to be small. A spline stub 190 then torsionally couples the shaft 188 to the chain case drive mechanism 192.

[0094] To assemble this design, and with reference to Figure 23, the drive shaft 188 is positioned slightly off center from the tunnel, enough for the chain case end of the shaft to clear the tunnel wall. A notch is present in the tunnel wall for the free end (non-chain case end) of the shaft to pass through into the correct position. The drive shaft 188 is then moved toward the chain case 184 and pilots on the case bearing. The spline stub 190 is then inserted from the outside of the chain case 184 and torsionally couples the drive shaft 188 to the chain case drive mechanism 192. An access hole 187 is present in the case cover so the case does not need to be opened to install or remove the stub 190. A fastener 191 is then threadably received in the end of the shaft 188, closest to the case 184, clamping the drive shaft 188 to the chain case. This fastener 191 is then enclosed by a cover 194 for the access hole 187. Lastly, the free end of the shaft 188 is tightened against the main drive shaft bearing.

[0095] Both methods are very beneficial with the coaxial mount suspension arm (discussed above). This allows the track and drive shaft to be assembled to the suspension and the entire suspension/track assembly placed into the chassis all at once.

[0096] An important consideration in rear suspension design is maintaining track tension through suspension travel. If the track becomes loose, it will skip drive sprocket teeth and damage the track. Extremely loose tracks can derail. Excessively tight tracks will yield high stresses on components and cause track vibration, stretch, and damage.

[0097] Achieving the mount points for desirable rate and kinematics is only half the challenge of snowmobile suspension design. Packaging a track around the suspension is the other. Traditional suspensions sacrifice more optimum suspension geometry to provide track tensioning and packaging which can be extremely difficult to manage.

[0098] The suspension of the present invention packages the suspension around the track. That is, the track actually passes through one or more suspension components. This design yields superb track tension values throughout travel. Due to a lack of a carrier (upper) track wheel, and coaxial mounting of the swing arm and drive sprocket, the tension in the illustrated embodiments only relies on the drive sprocket wheel 88 and idler wheels 108 to keep the track tight to prevent “unwrapping” around the rail bend profile as shown in Figures 15-17. Track tension is easily tuned by sizing the idler wheel 108 with the drive wheel 88. Therefore, elimination of carrier wheel in conjunction with coaxial swing arm mounting greatly simplifies track tensioning in the illustrated embodiments.

[0099] With respect now to Figure 24, A-shaped rear pivot 96 will be described in greater detail. As mentioned above, A-shaped rear pivot 96 connects bell crank 38 to LFE 32. A-shaped rear pivot 96 is shown pivotably coupled to bell crank 38 by connection 98. A first arm 100 of pivot 96 is pivotably coupled to slide rails 12 at location 102. As shown best in Figure 25, second arm 104 of pivot 96 is coupled to slide rails 12 by a coupling slider 106, having an arced slot 107 that facilitates coupling between the front and rear. A block 105 coupled to arm 104 moves back and forth in slot 107.

[00100] This improved suspension also uses a changing “rail link” length to facilitate coupling. However, the pivot is considerably longer than traditional due to packaging around and outside the track envelope so that simple bumpers on the slide rail would not work effectively. Instead, the pivot is shaped as a triangle and the relative angle between the pivot and slide rails is limited by a curved slider mechanism, as described with reference to Figure 25.

[00101] The advantages of this system are threefold. First, the horizontal length between the pivot-to-rail mount and the slider can be adjusted to reduce or increase the load within the slider system. Second, the load between these two points is shared by the slide rail itself so no additional structure is required on the pivot. Third, slots in the

slider system provide lateral stiffness to the slide rails so additional components are not required to increase lateral strength or stiffness.

[00102] The following outlines the function of each component in the embodiment shown in Figures 15-17. The swing arm 80 is pivotally connected to the chassis coaxial with the drive shaft 86, low and forward on the slide rail 12 to facilitate weight transfer. The pivot 96 is pivotally connected to the slide rail 12 near the rear, and to an arced slot 107 that facilitates coupling. The pivot 96 is “locked” to the slide rail 12 at the extents of the slot 107. The geometry is coupled to the front when the pivot is at the bottom, to the rear when the pivot is at the top. The crank 38 is pivotally connected to the pivot 96 at one end 54 and the chassis at the other end 50. The crank 38 acts as the rear arm of the four-link. The preload spring 90 is connected between the swing arm 80 and the slide rail 12. This spring 90 is used for preload bias and does not appreciably affect rate. The main spring/damper 32 is connected between the crank 38 and the chassis. The location on both determines how progressive the suspension is.

[00103] As snowmobiles develop, accommodations in the chassis must be made for faster, more powerful engines, longer travel suspension, more precision handling, and improved durability. This means the chassis must be stronger and stiffer. The most intuitive method to increase strength and stiffness is to directly connect the suspension hard points with more significant structure than a thin walled tunnel can provide. The result is a direct load path between the front suspension mounts, the rider input points, and the rear suspension mount points, such that the load path can only terminate in a structurally durable member of the chassis.

[00104] The chassis structure, especially in the rear section of the snowmobile, becomes considerably more important when the LFE reacts outside the suspension, as described in the above discussion. In this case, rear suspension loads are not only internal to the suspension, but are directed into the chassis such that the chassis structure is an integral part of the suspension. As discussed above, a suspension

system is described for support for the LFE 32 above the tunnel 40. The sub frame 70 was shown in Figure 15 for mounting LFE 32 above tunnel 40.

[00105] With reference now to Figs. 26 and 27, a further embodiment will be described. This embodiment shows a snowmobile rear suspension having a bell crank 238, where bell crank 238 is connected to tunnel 40 at a front end 250 and to a pivot link 296 at 298, in a similar manner as previously described with respect to Fig. 15.

[00106] In addition, snowmobile suspension includes a carrier assembly 210 having frame arms 212, 214 which suspend carrier rollers 216. Track 39 would wrap around carrier rollers 216, around a drive roller 88 (Figs. 16, 17), around rail beams 12, and around idler rollers 108.

[00107] In this embodiment, the angle of the track 39 is increased from the angle of the track as depicted in Fig. 17, without carrier assembly 210. The tension of the track 39, in the embodiment of Figs 26-27, has a vertical and horizontal component, with an increased vertical component, over the embodiment of Fig. 17. The vertical component is reactive in the direction of the suspension. The carrier assembly 210, and the angle of the track ($\emptyset$), allows modification of the tractive force, and the stress on the rail beams 12, versus the vertical force. An increase to the angle $\emptyset$, decreases the stiffness of the suspension, and makes the suspension more supple. In the embodiment of Figs 26-27, $\emptyset$ is approximately 24°.

[00108] In some suspension designs, the rail beams have plastic sliders. When the suspension jounces, the track can hit the sliders. This design prevents the track from hitting any part of the rail beams.

[00109] In summary, the embodiment of Figs. 26 and 27 reduces the so-called noise, vibration and harshness (NVH) by keeping the track off of any plastic sliders on the rail beams. This design also reduces the load into the rail beams by reducing the horizontal component of the track vector as mentioned above. Finally, this design

reduces rear rail stiffness by adding a larger vertical component of the track vector on the idler.

[00110] Finally, while the bell crank 238 provides a convenient location for the mounting of the carrier rollers, the carrier rollers could be mounted within the tunnel 40, and utilize the bell crank as shown in Figs. 15-17.

[00111] While this invention has been described as having an exemplary design, the present invention may be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains.

What is claimed is:

1. A snowmobile (10) comprising a frame (41); endless track (39) for driving the snowmobile; slide rails (12) for mounting the endless track; at least one linkage between the slide rails and frame, the linkage comprising a pivot link (296), where the pivot link pivots in response to movement between the slide rails and the frame; and at least one linear force element (LFE, 32) positioned between the linkage and the frame, whereby pivotal movement of the linkage strokes the LFE; characterized in that carrier rollers (216) are coupled to the at least one linkage, with the endless track (39) positioned over the carrier rollers.
2. The snowmobile of claim 1, wherein the carrier rollers are suspended by frame arms (212, 214) attached to the at least one linkage.
3. The snowmobile of claim 1, wherein the at least one linkage further comprises a bell crank (238), which connects to one end of the LFE and to the pivot link.
4. The snowmobile of claim 3, wherein the carrier rollers are suspended by frame arms (212, 214) attached to the bell crank.
5. The snowmobile of any of claims 1-4, further comprising rear idler rollers (108) coupled to the slide rails, where the endless track extends over both the rear idler rollers and the carrier rollers.
6. The snowmobile of claim 5, wherein the endless track extends at an angle of approximately 20-30° at steady state between the rear idler rollers and the carrier rollers.
7. The snowmobile of claim 6, wherein the endless track extends at an angle of approximately 24° at steady state.

8. The snowmobile of claim 1, wherein the LFE is positioned above the carrier rollers.
9. A snowmobile (10) comprising a frame (41); endless track (39) for driving the snowmobile; slide rails (12) for mounting endless track; at least one linkage between the slide rails and frame, with a portion of the linkage being positioned below the endless track and a portion of the linkage positioned above the endless track; and at least one linear force element (LFE, 32) positioned substantially horizontally, with one end attached to the frame and one end connected to the at least one linkage, characterized by a track tensioner coupled to the portion of the linkage positioned above the endless track with the endless track positioned against the track tensioner.
10. The snowmobile of claim 9, wherein the at least LFE is positioned above the frame and the track tensioner.
11. The snowmobile of claim 9 or 10, wherein the at least one LFE is substantially horizontal throughout its movement.
12. The snowmobile of any of claims 9-11, wherein the at least one linkage is comprised of a pivot link (296) attached to the slide rails.
13. The snowmobile of claim 12, further comprising a bell crank (238) pivotally mounted between the frame and the pivot link.
14. The snowmobile of claim 13, wherein one end of the LFE connects to the bell crank.
15. The snowmobile of claim 13 or 14, wherein the track tensioner is comprised of carrier rollers (216) suspended by frame arms (212, 214) attached to the bell crank.

16. The snowmobile of claim 15, wherein the bell crank is pyramidally shaped, with front corners (250) attached to the frame, rear corners (298) operatively coupled to the slide rails through the pivot link, and the apex (236) attached to the LFE.

17. The snowmobile of claim 15 or 16, further comprising rear idler rollers (108) coupled to the slide rails, where the endless track extends over both the rear idler rollers and the carrier rollers.

18. The snowmobile of claim 17, wherein the endless track extends at an angle of approximately 20-30° at steady state.

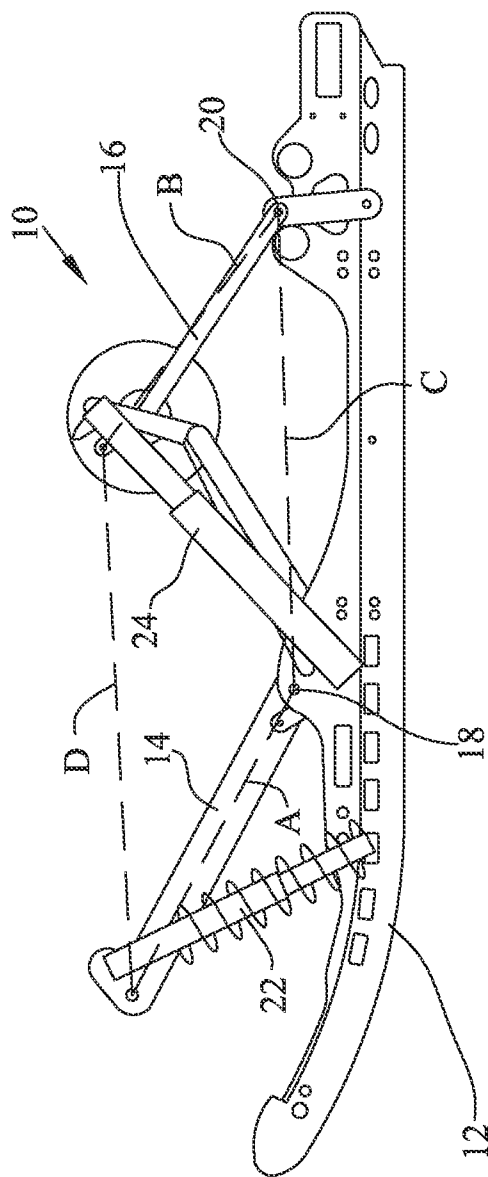
19. The snowmobile of claim 18, wherein the endless track extends at an angle of approximately 24° at steady state.

20. A snowmobile (10) comprising a frame (41); slide rails (12) coupled to the frame; endless track (39) mounted to the slide rails; a suspension assembly () coupling the slide rails to the frame; at least one linear force element (LFE, 32) positioned outside of the envelope defined by the endless track, one end of the LFE being attached to the frame and the opposite end being attached to the suspension assembly; characterized in that carrier rollers are coupled to the suspension assembly, with the endless track passing through the suspension assembly and over the carrier rollers.

21. The snowmobile suspension system of claim 20, wherein the suspension assembly comprises a linkage which pivots in response to movement between the slide rails and the frame, and the LFE is positioned between the linkage and the frame, whereby pivotal movement of the linkage strokes the LFE.

22. The snowmobile of claim 20 or 21, wherein the at least one linkage is comprised of a pivot link (296) attached to the slide rails.

23. The snowmobile of claim 22, wherein the at least one linkage further comprises a bell crank (238), pivotally mounted between the frame and the pivot link.
24. The snowmobile of claim 23, wherein one end of the LFE connects to the bell crank.
25. The snowmobile of claim 23 or 24, wherein the bell crank is pyramidally shaped, with the carrier rollers coupled to the bell crank.
26. The snowmobile of any of claims 23-25, wherein the carrier rollers are suspended by frame arms attached to the bell crank.
27. The snowmobile of any of claims 20-26, further comprising rear idler rollers coupled to the slide rails, where the endless track extends around both the rear idler rollers and the carrier rollers.
28. The snowmobile of claim 27, wherein the endless track extends at an angle of approximately 20-30° at steady state.



Life

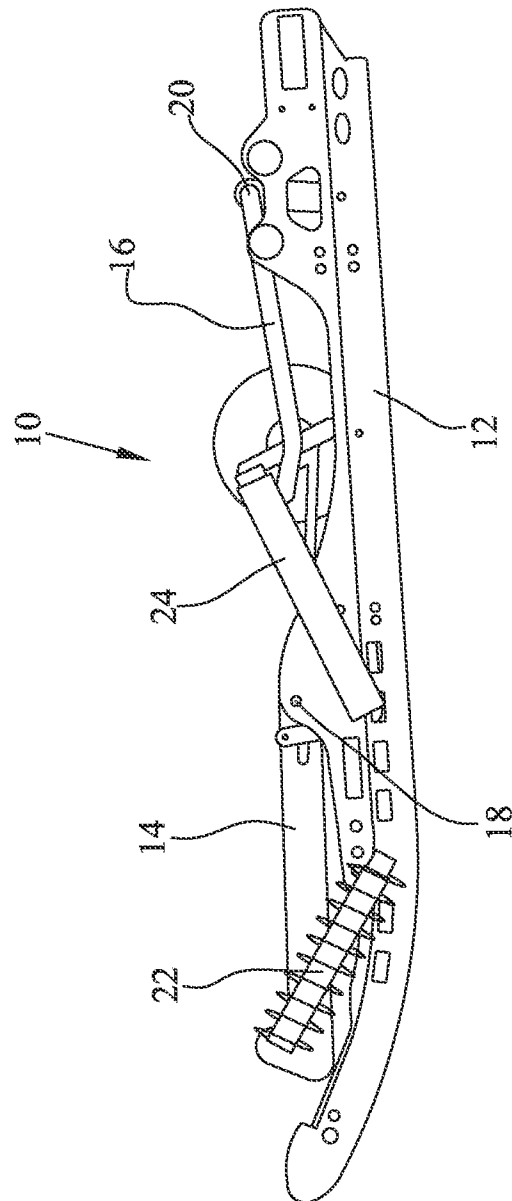


FIG. 2

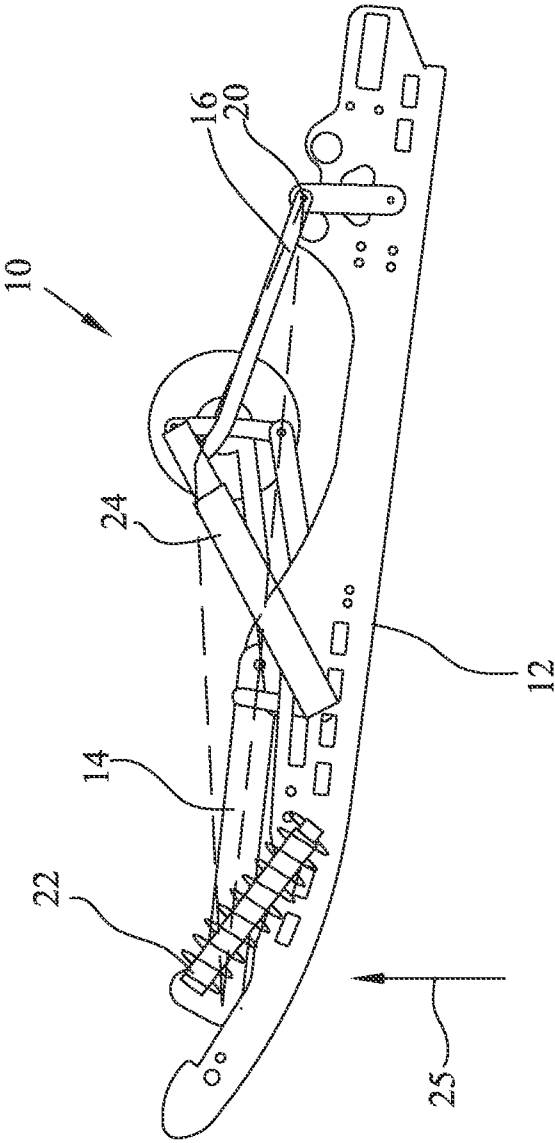


FIG. 3

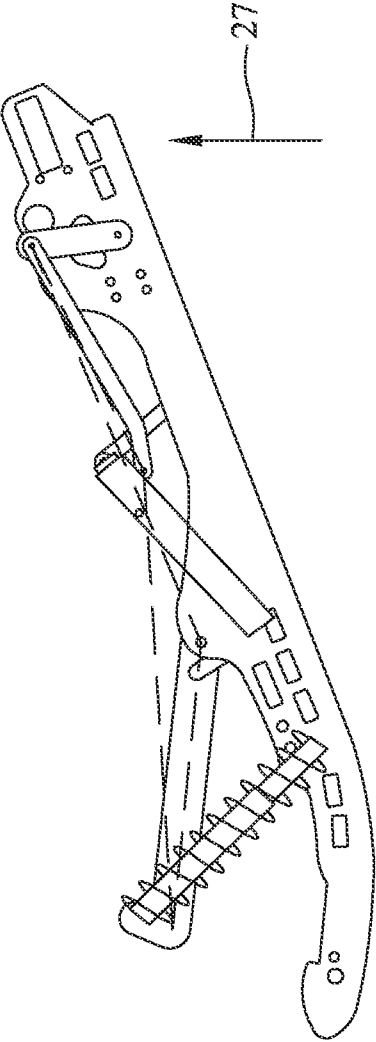


FIG. 4

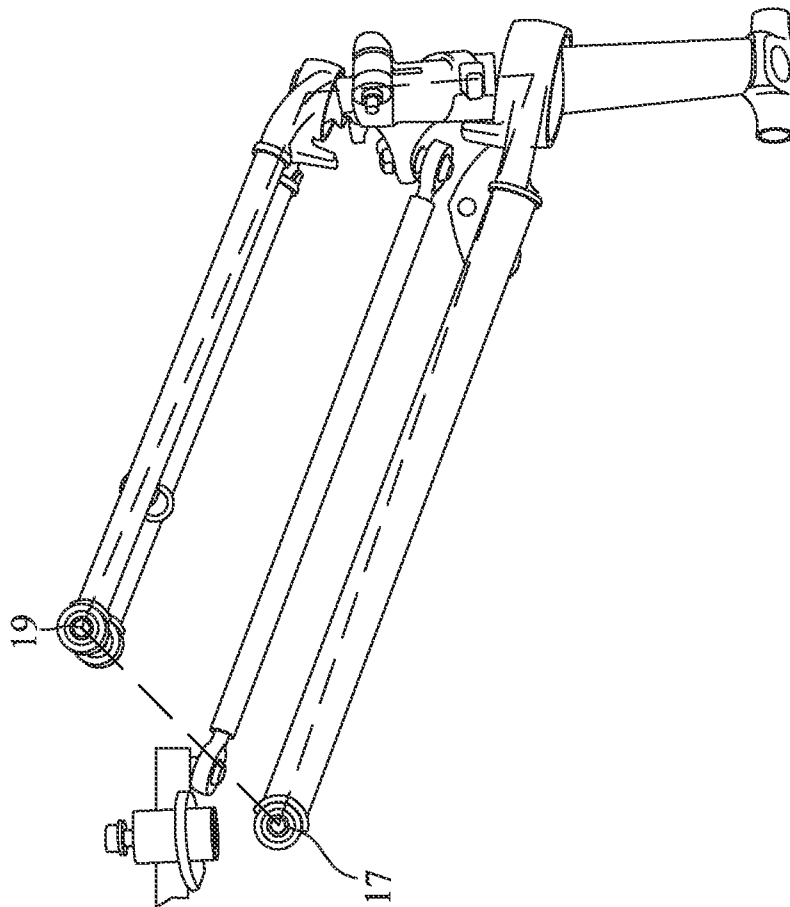


FIG. 5

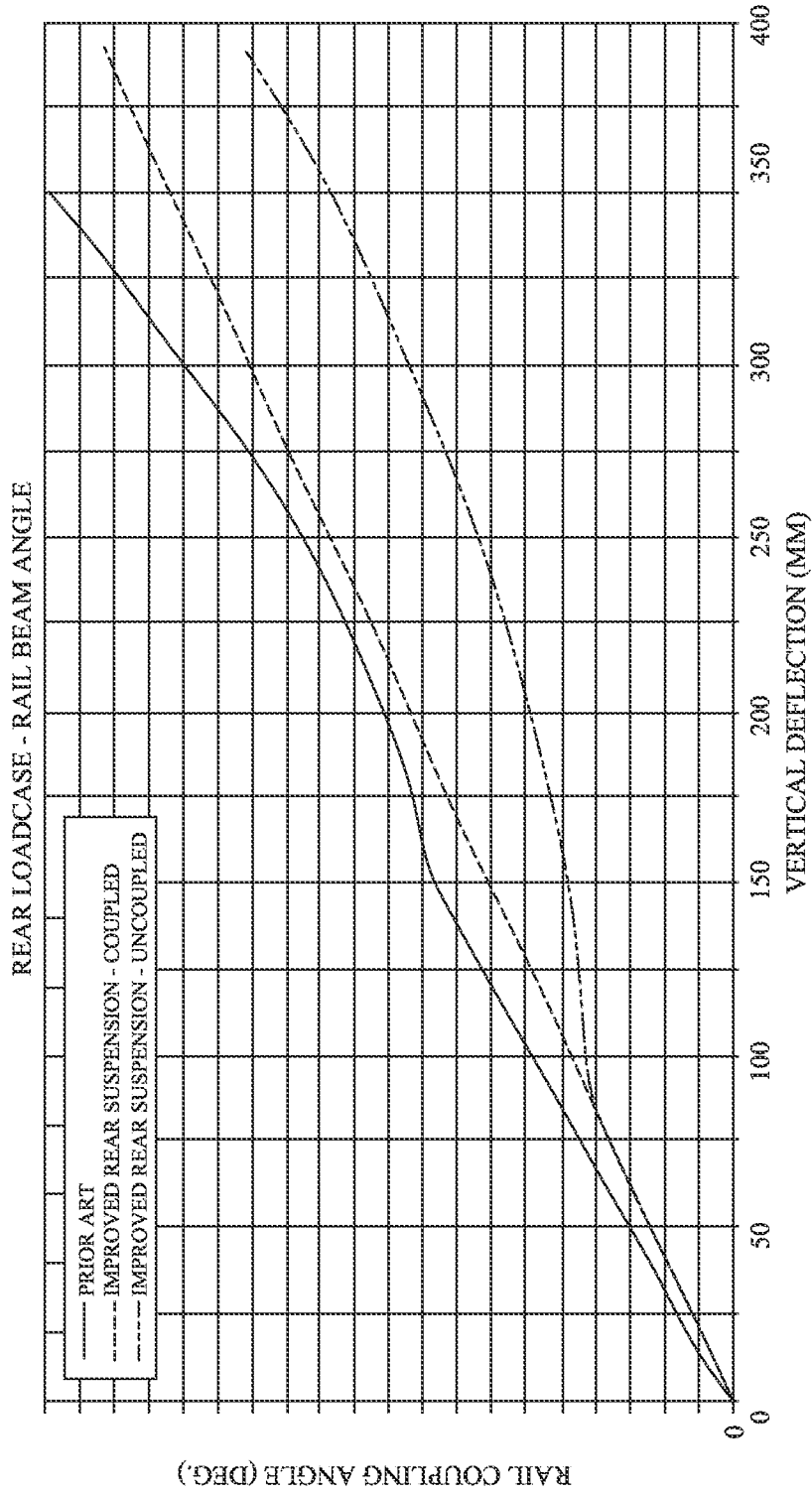


FIG. 6

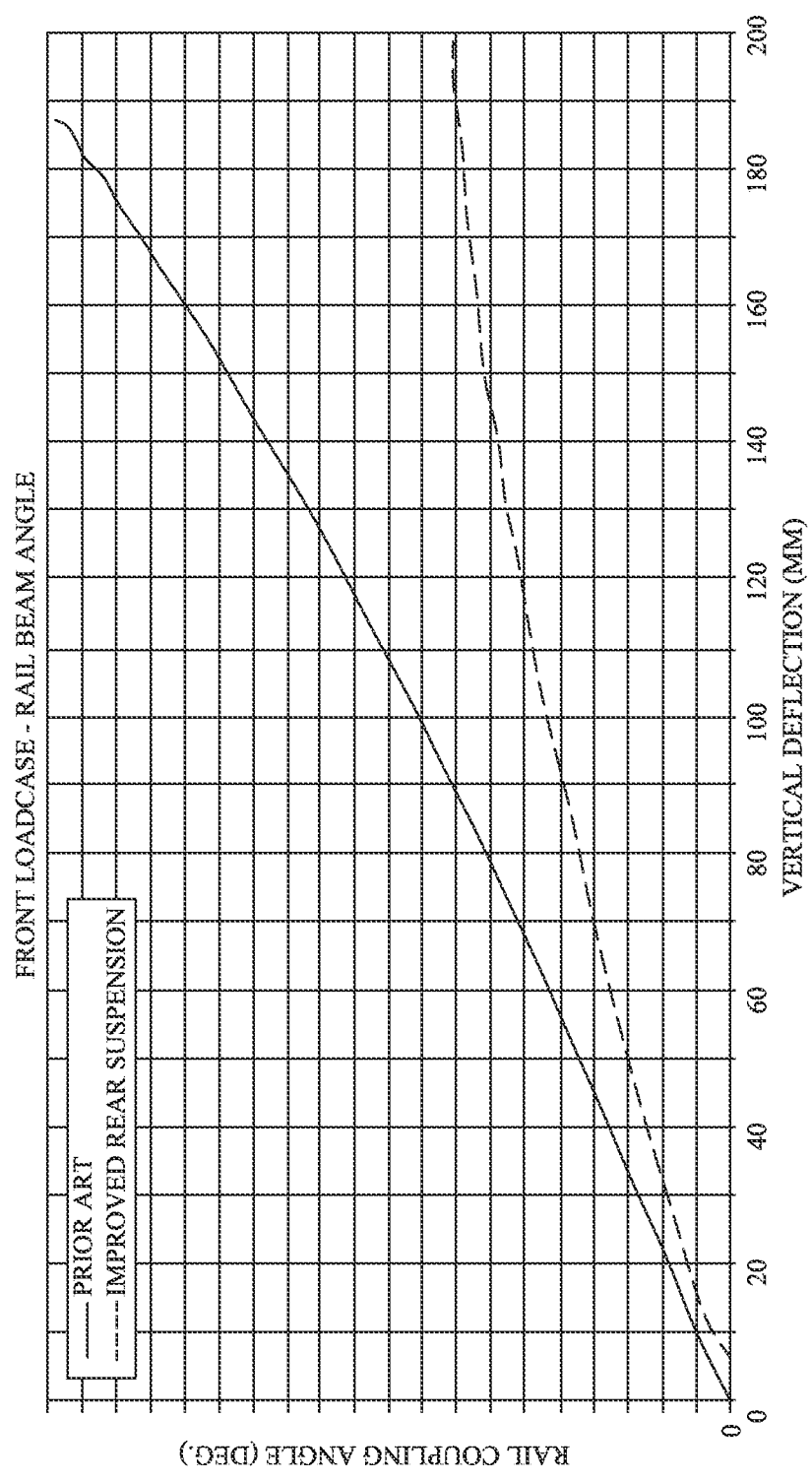


FIG. 7

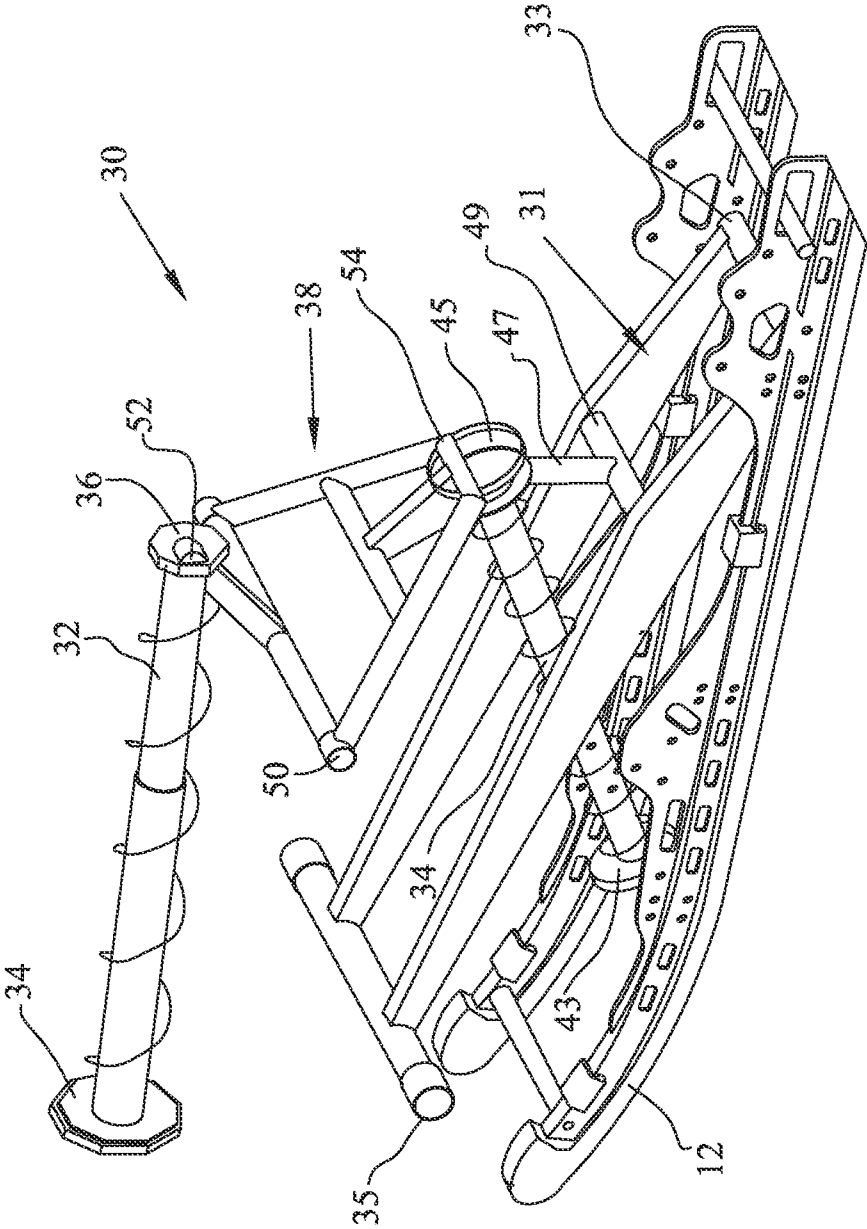


FIG. 8

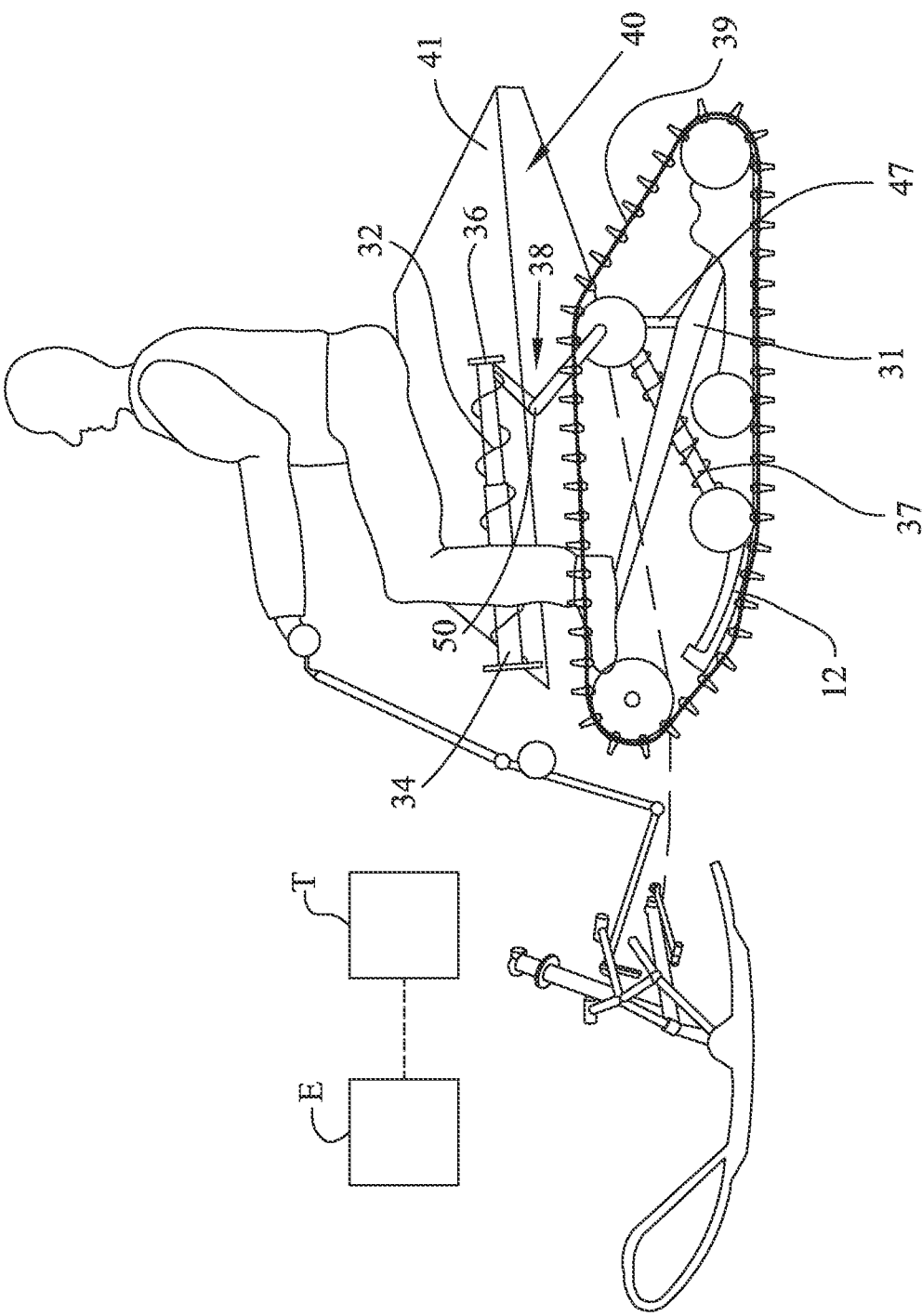


FIG. 9

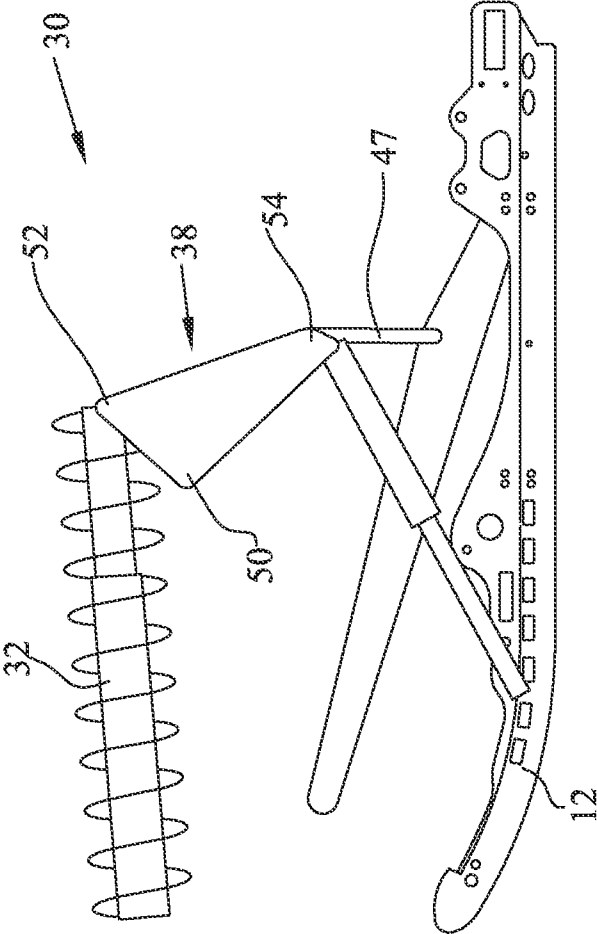


FIG. 10

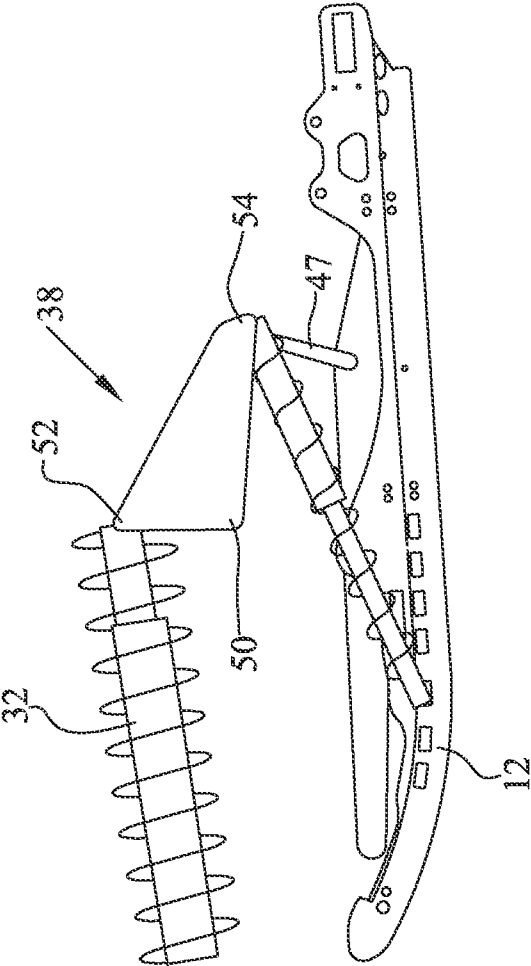


FIG. 11

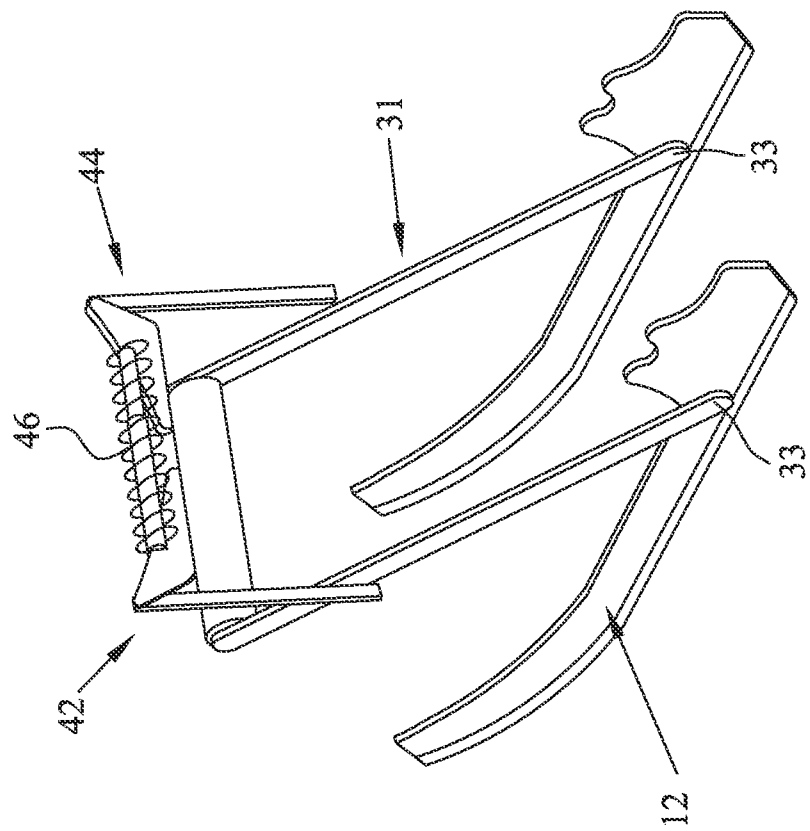


FIG. 12

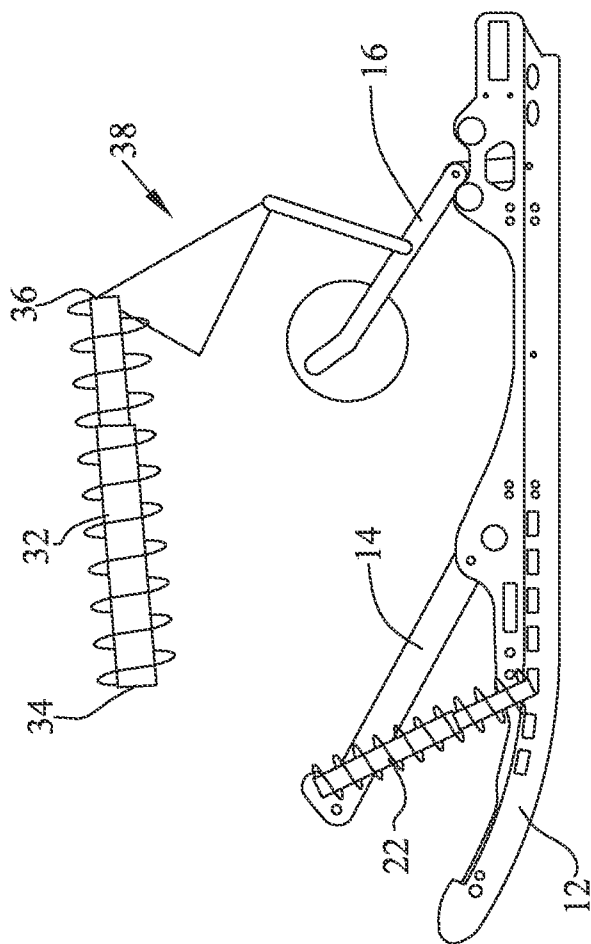


FIG. 13

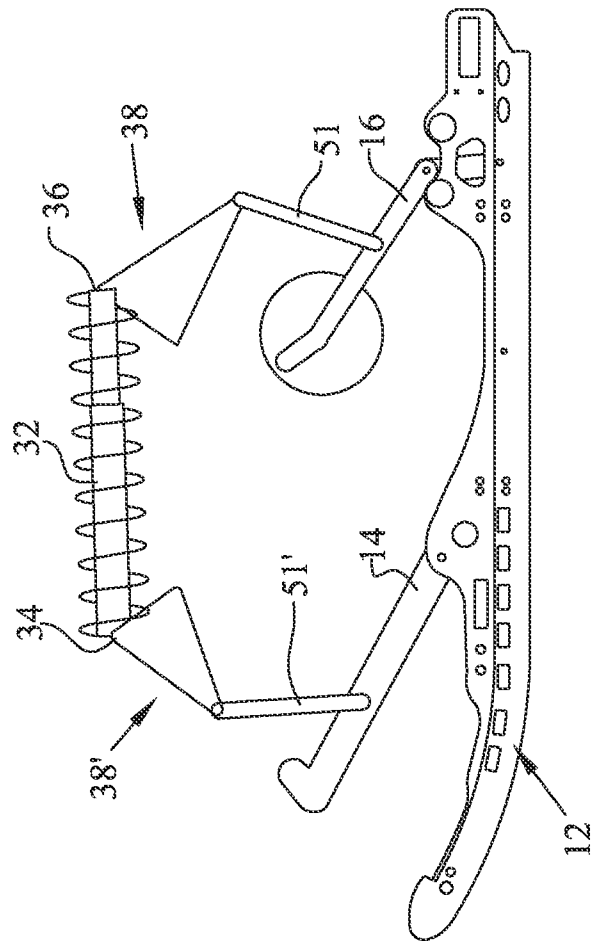
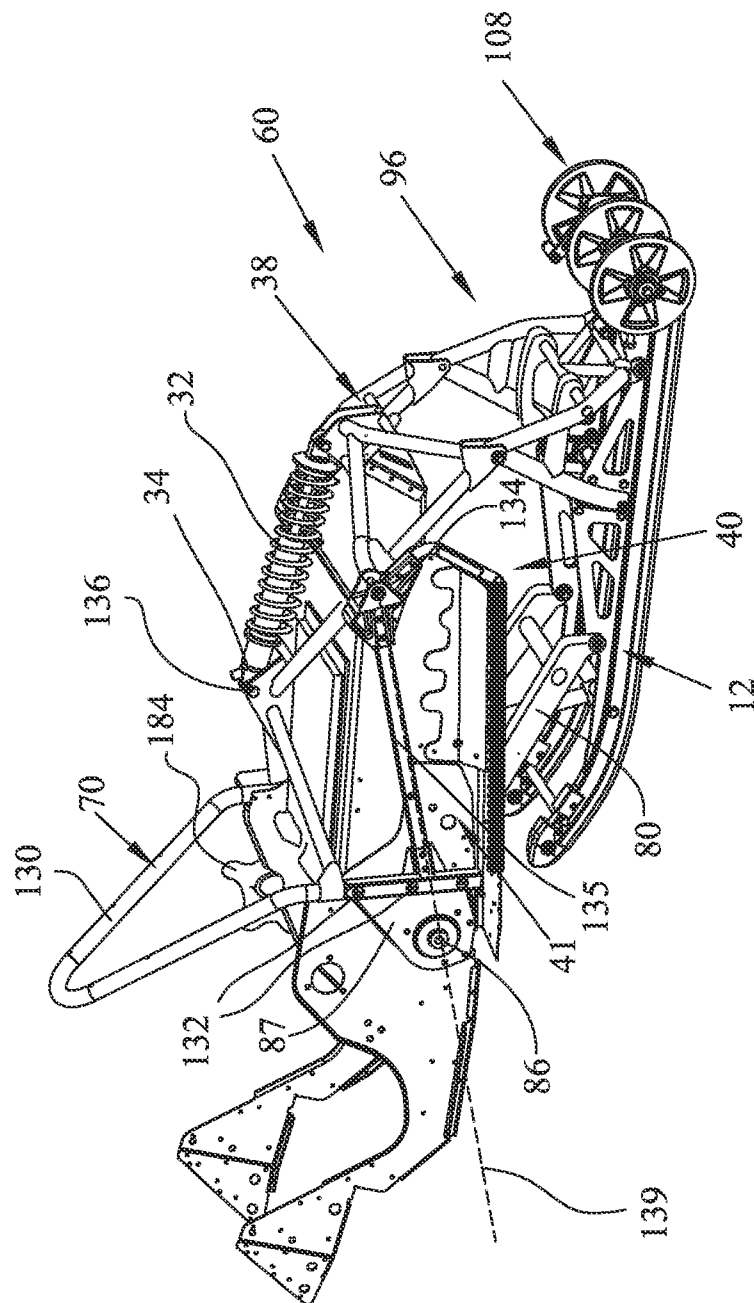


FIG. 14

**FIG. 15**

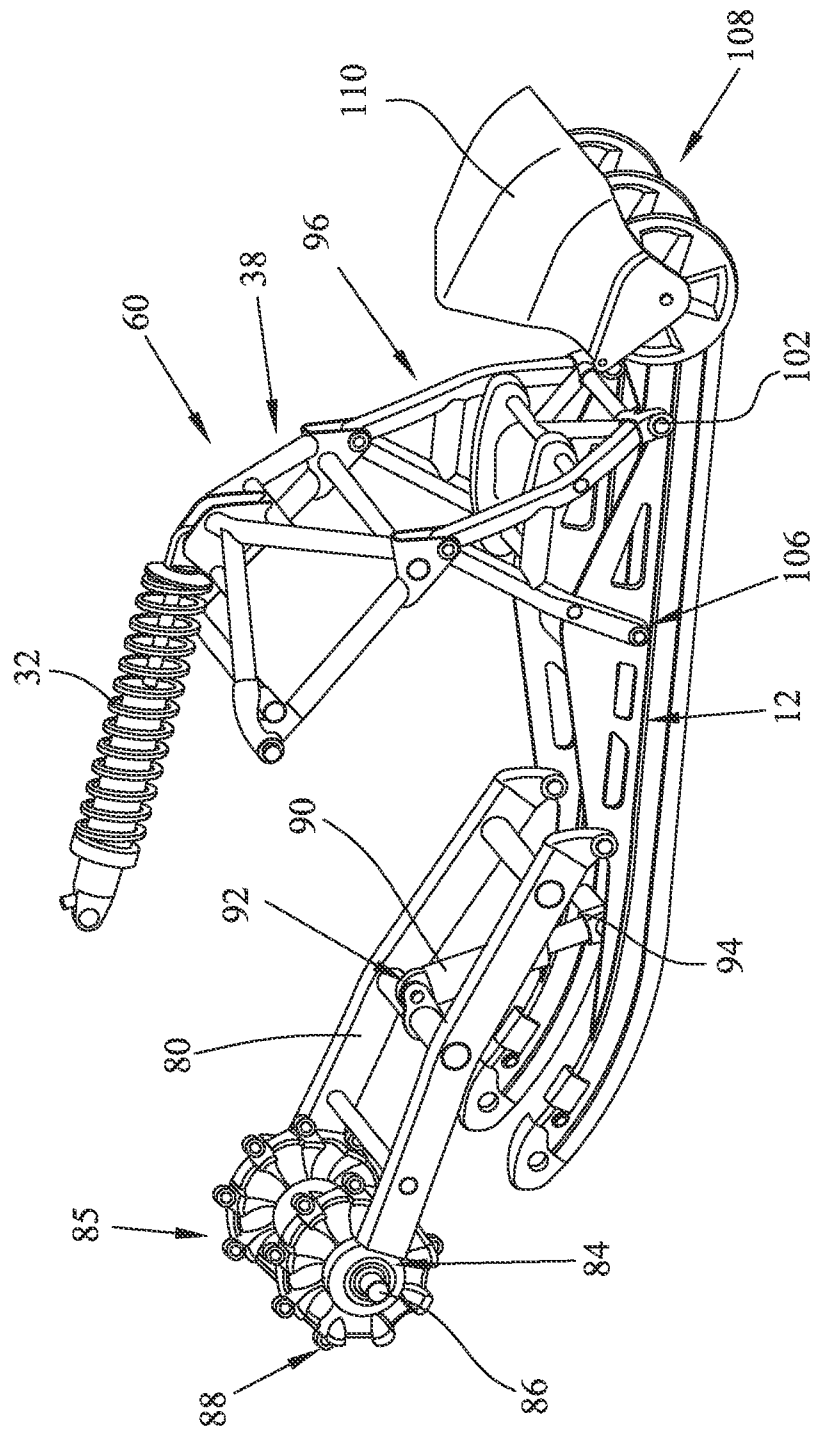


FIG. 16

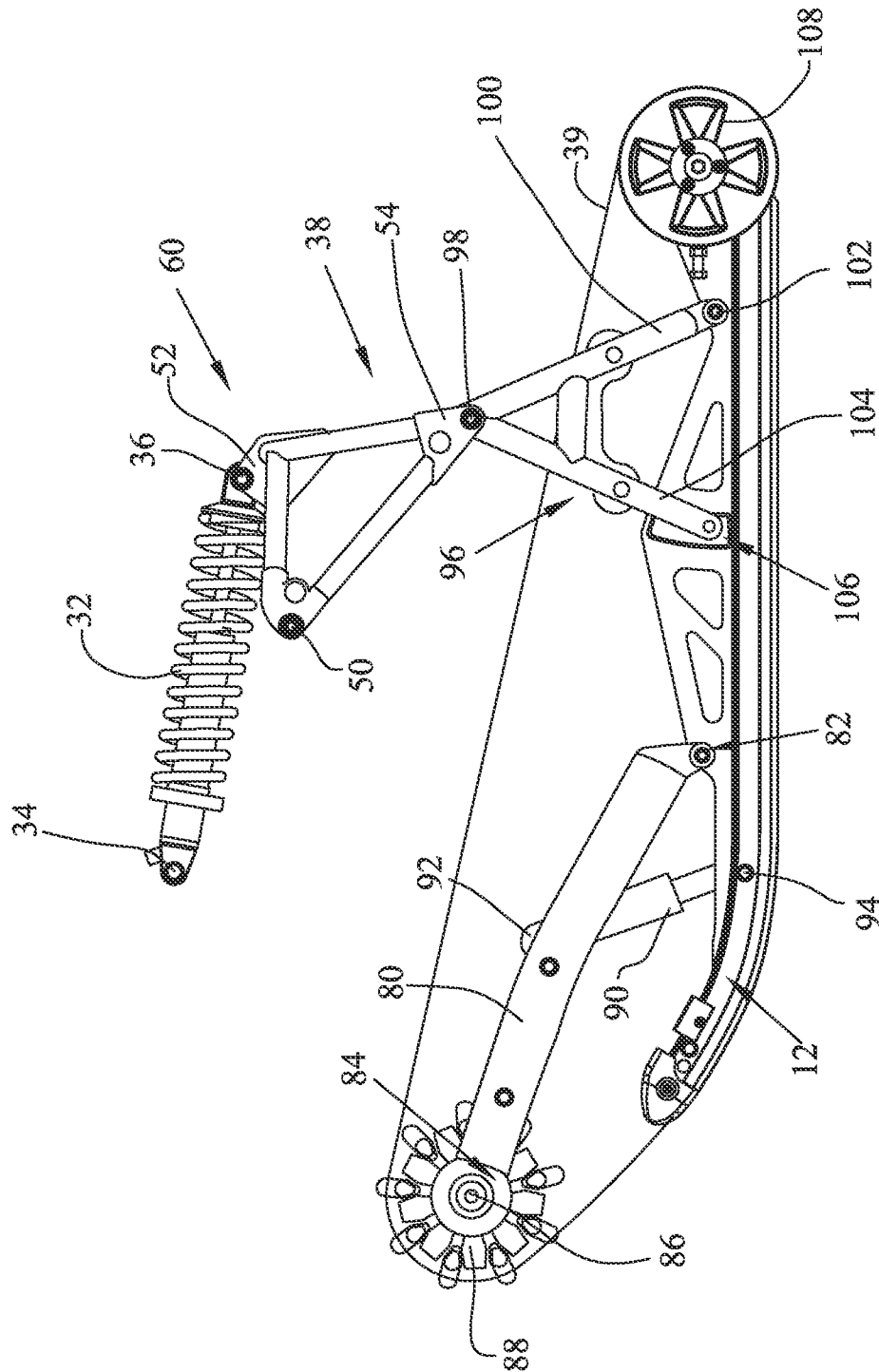


FIG. 17

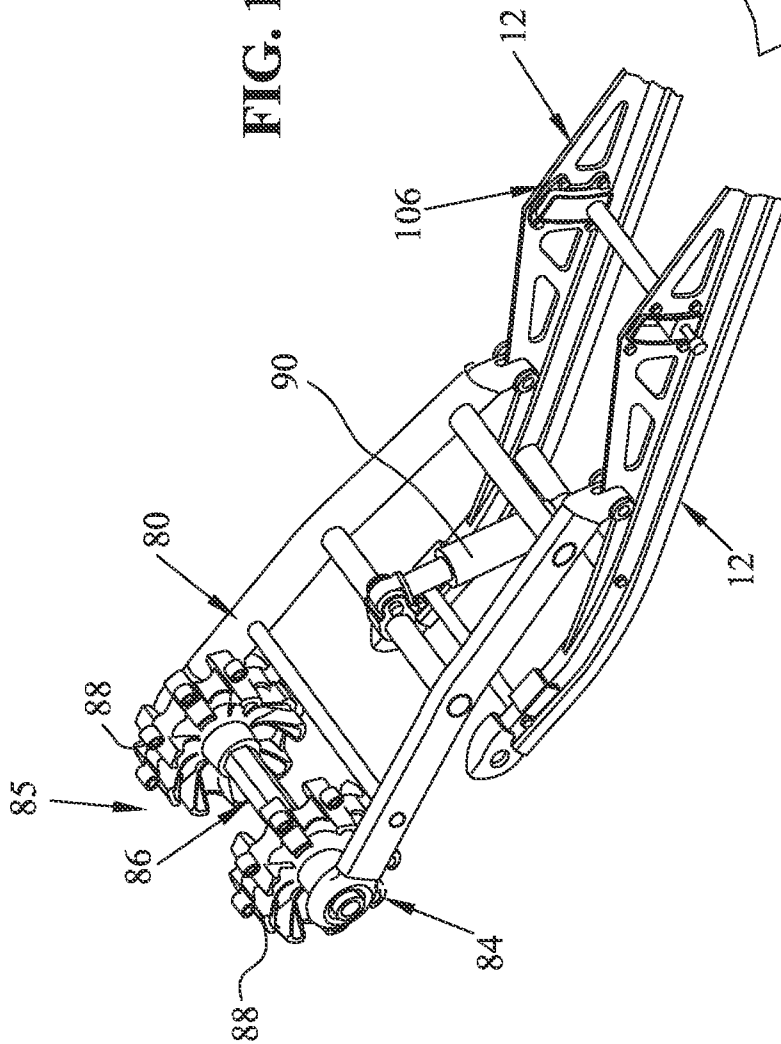


FIG. 18

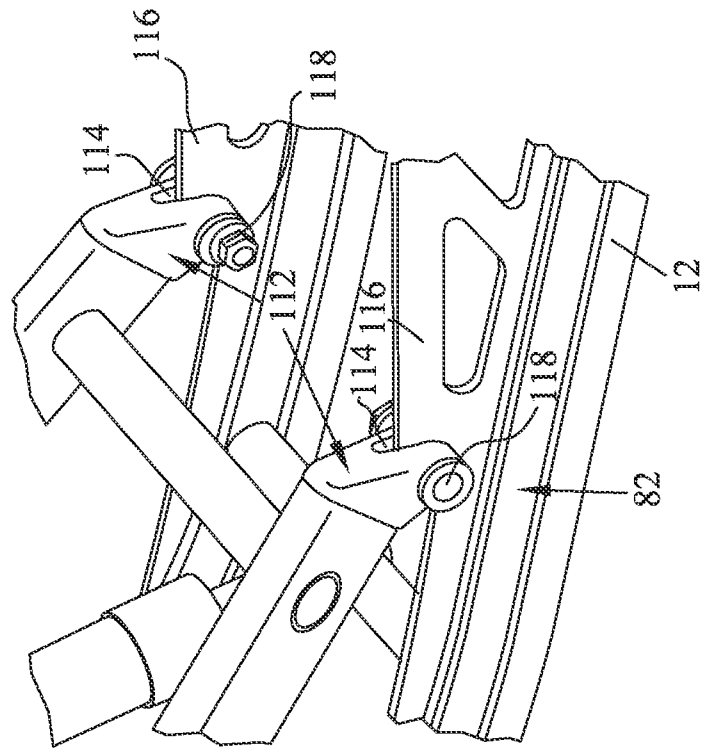


FIG. 19

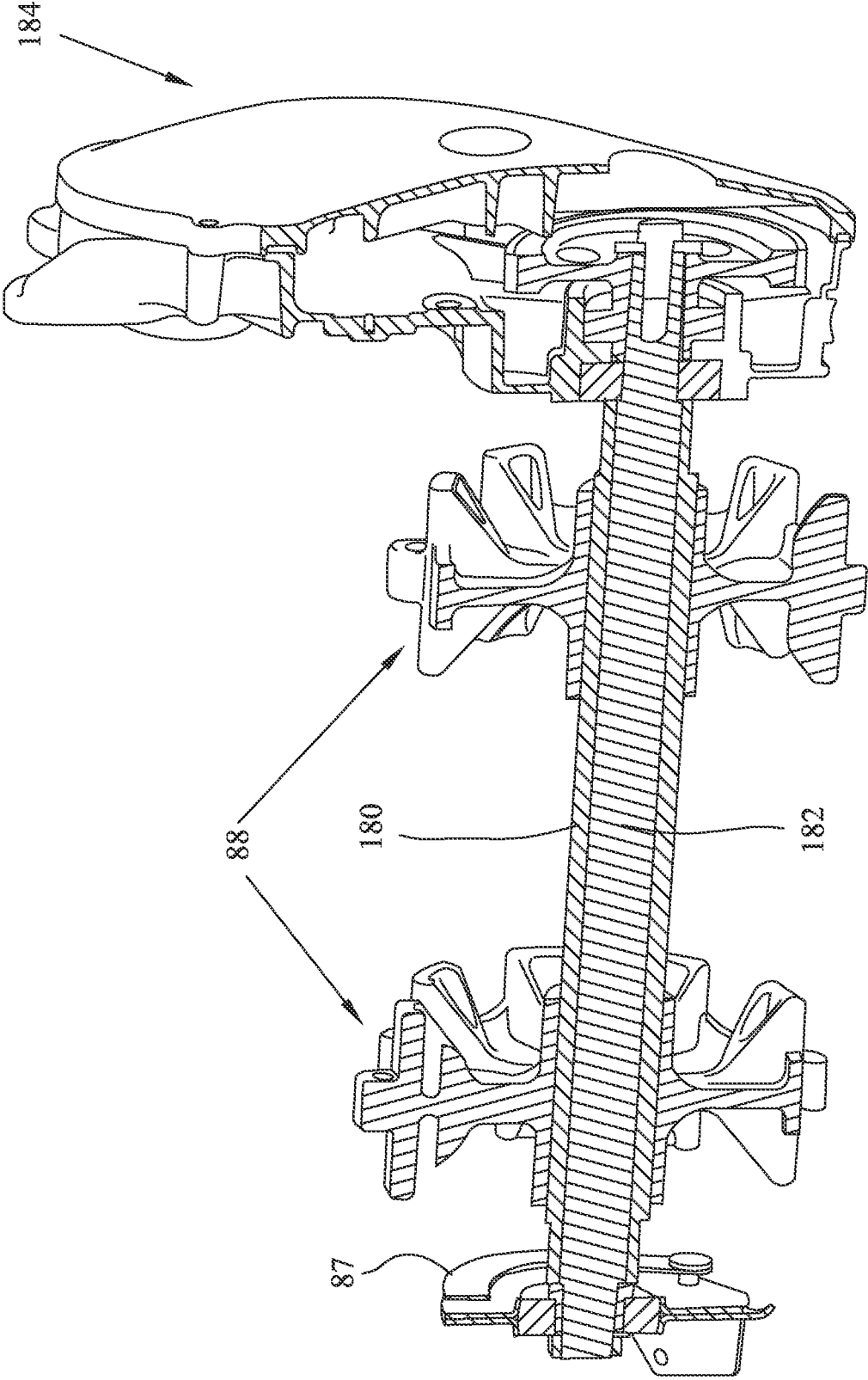


FIG. 20

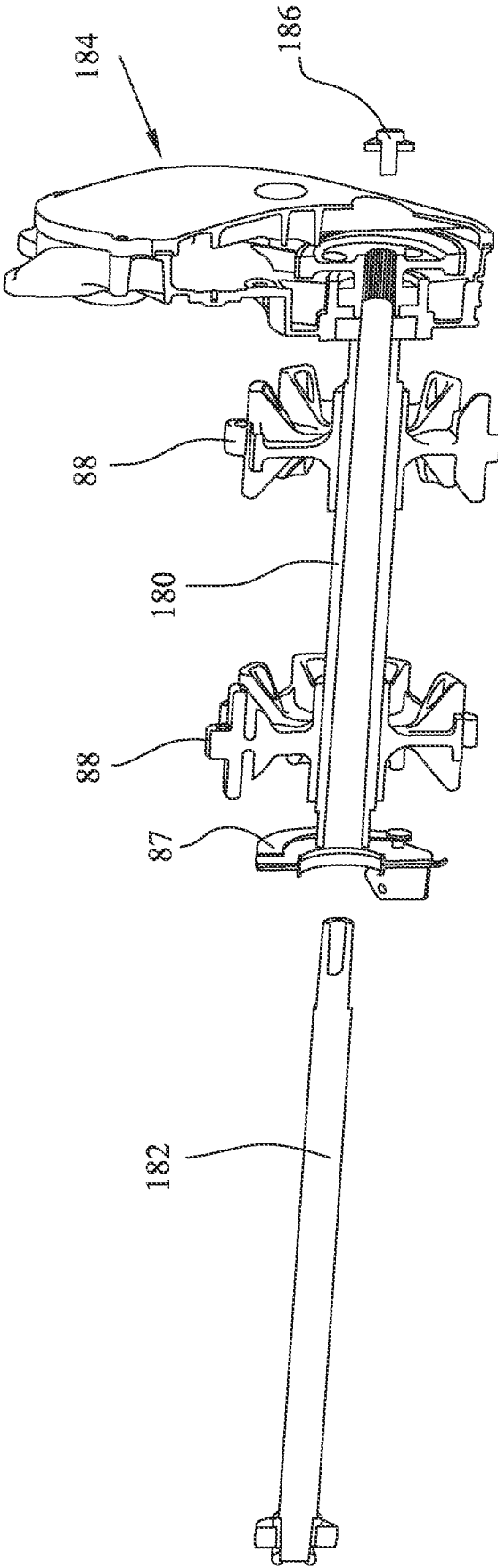


FIG. 21

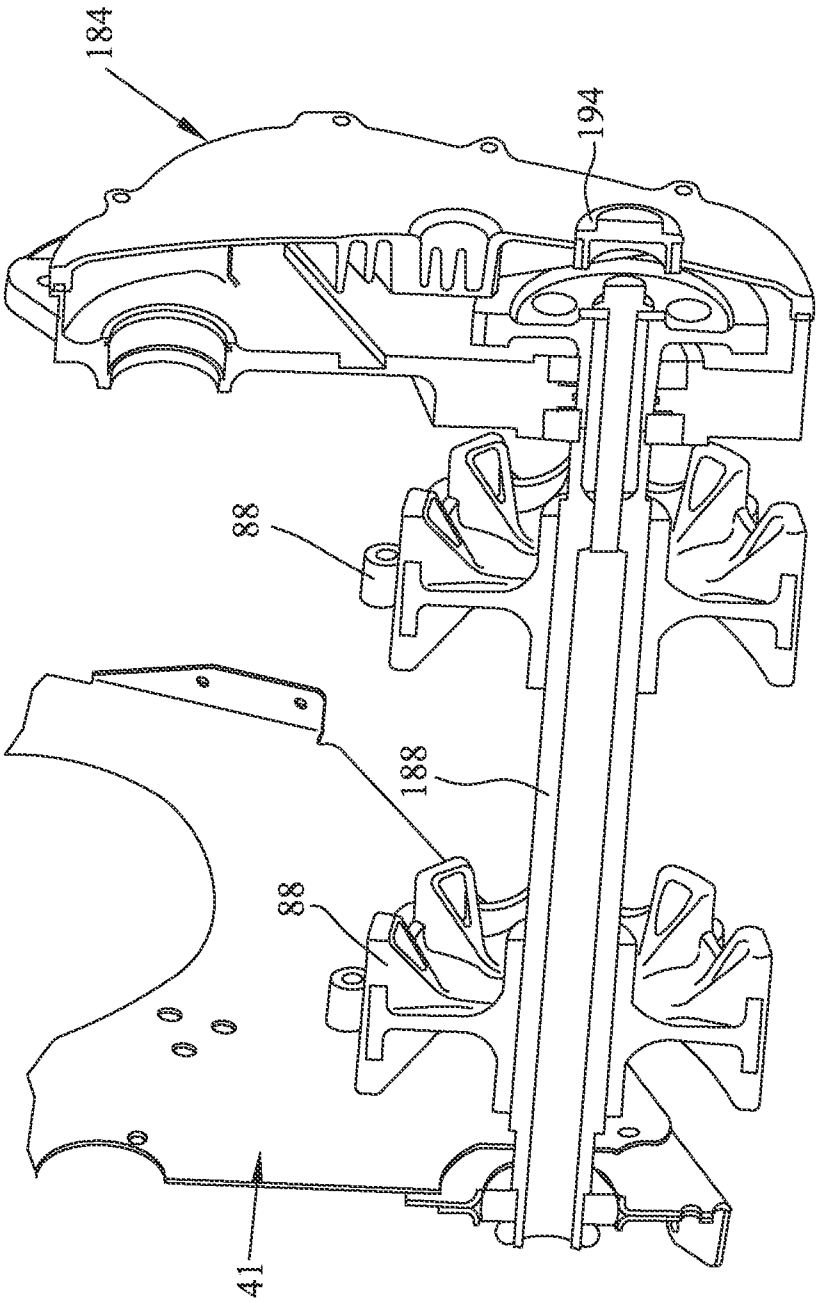


FIG. 22

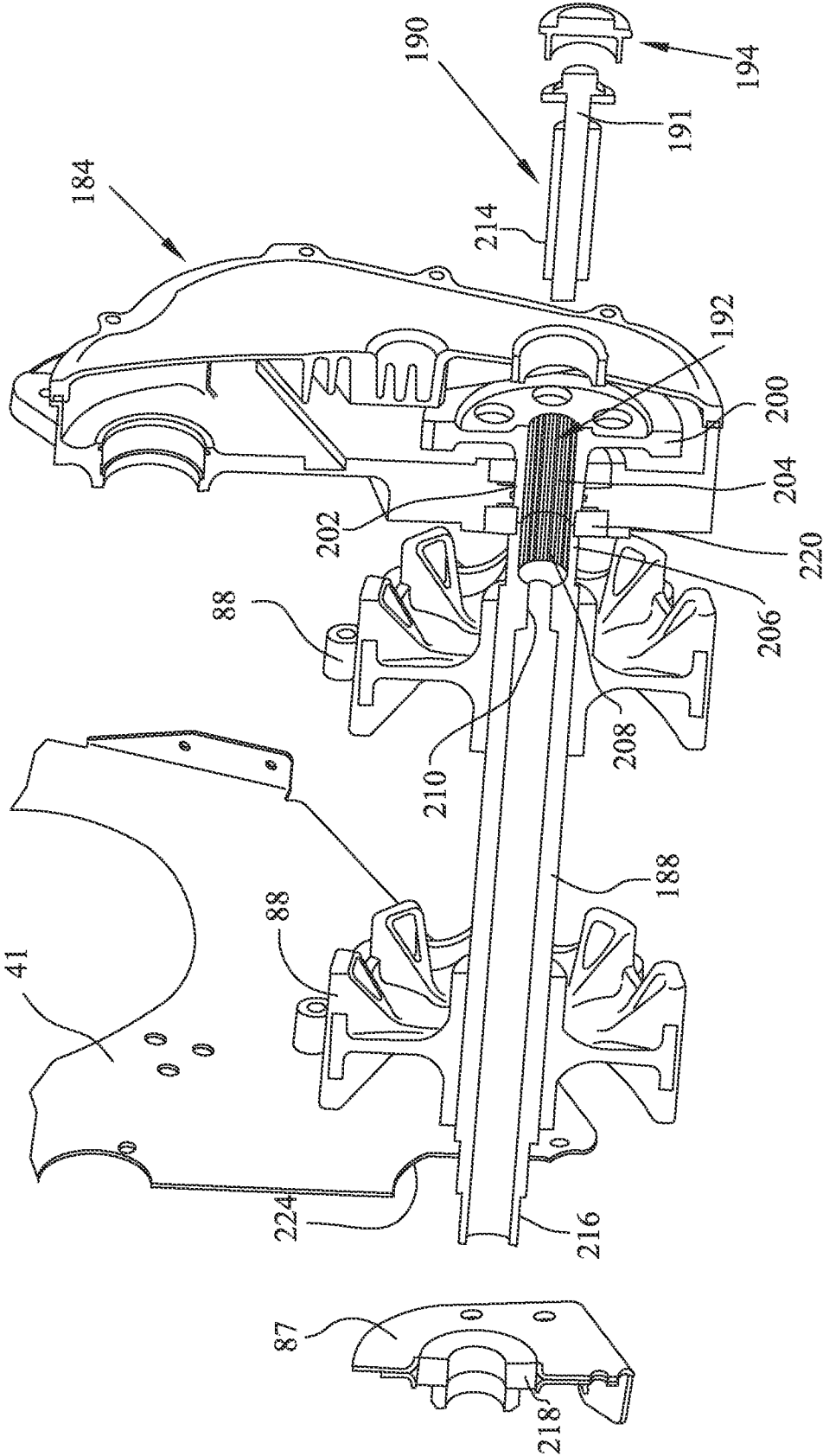


FIG. 23A

FIG. 23C

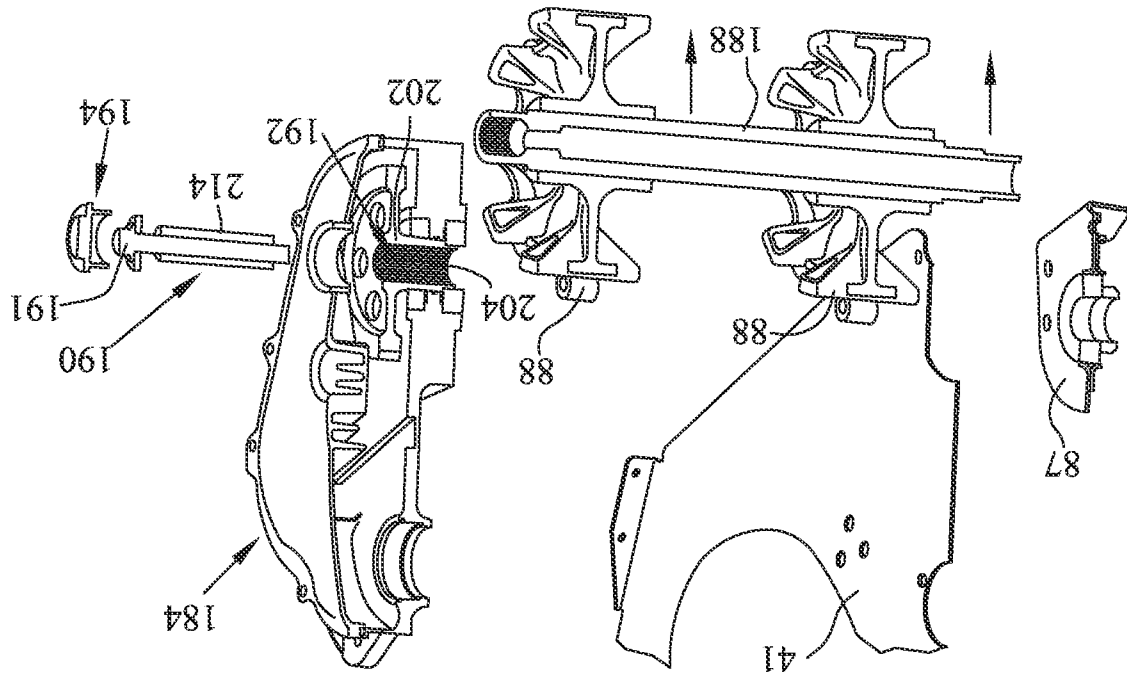
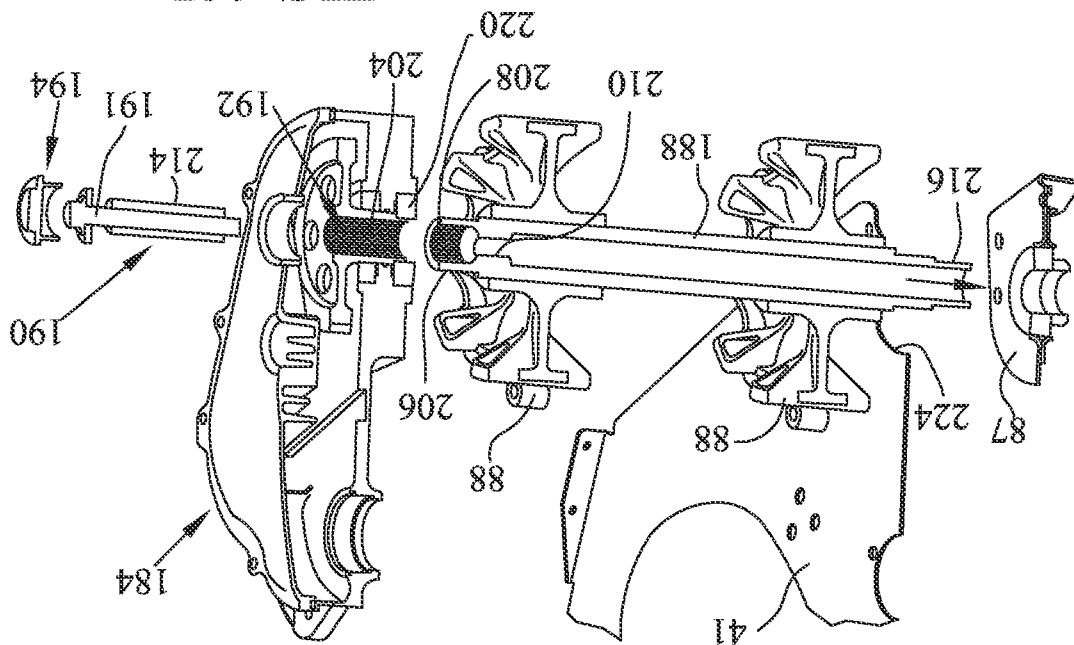


FIG. 23B



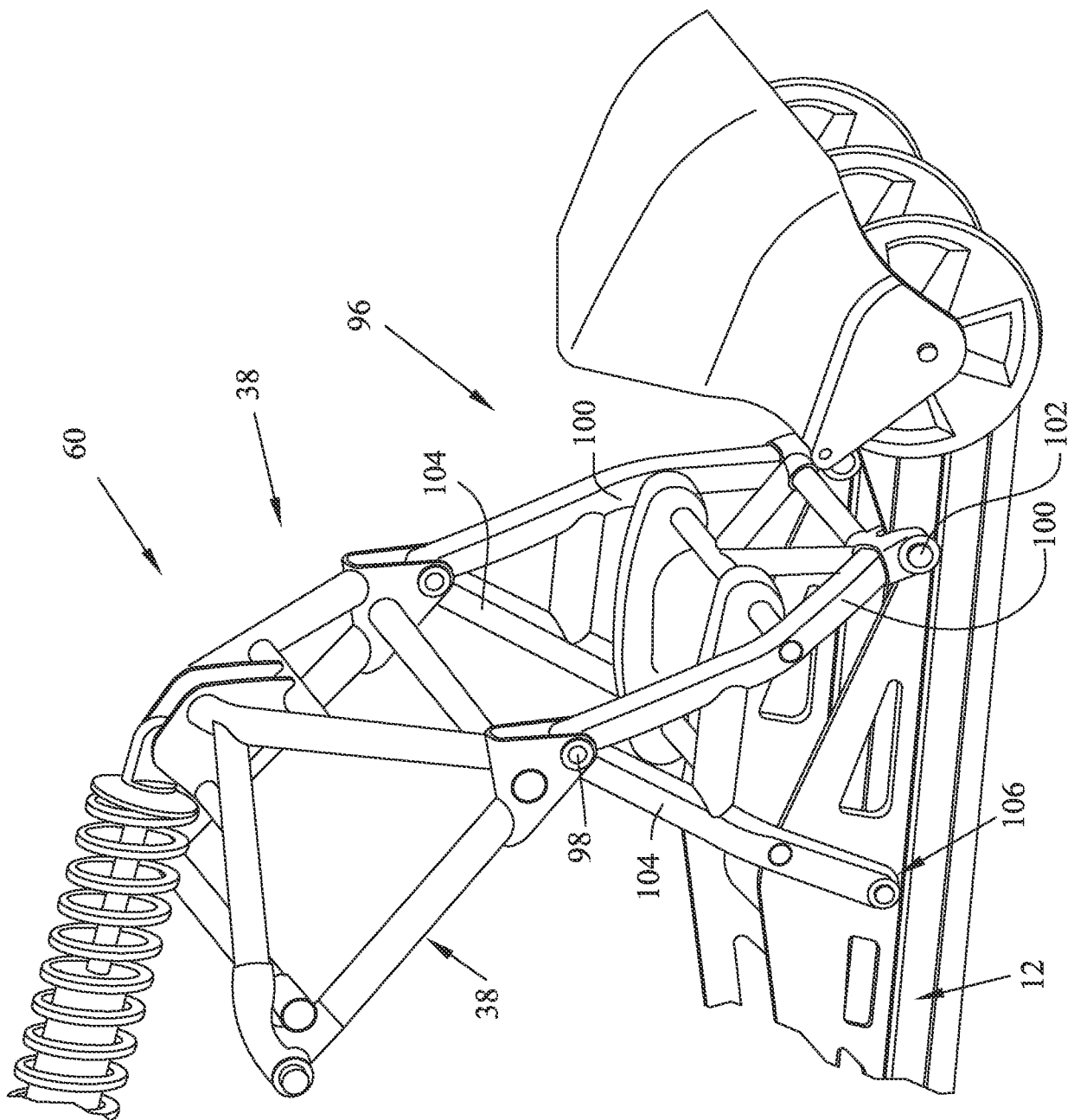


FIG. 24

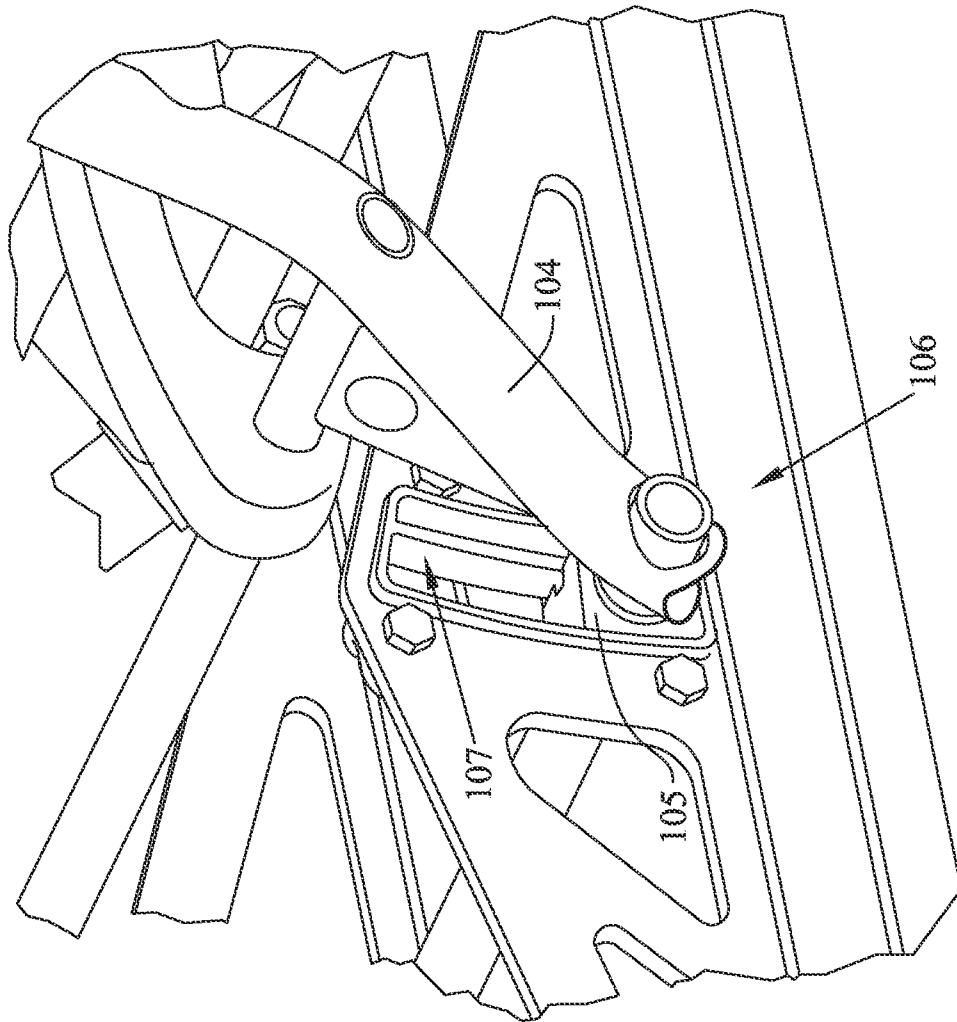


FIG. 25

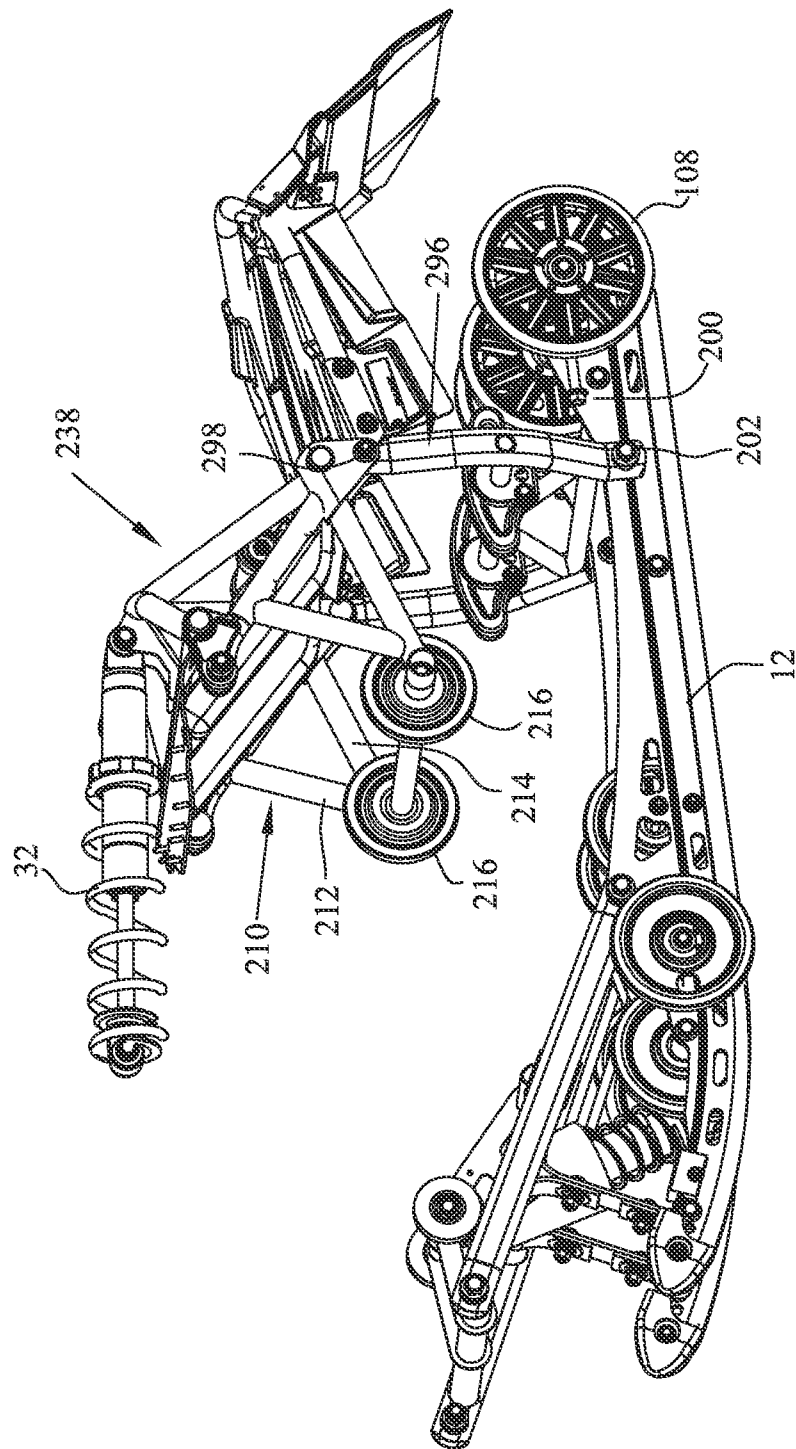


FIG. 26

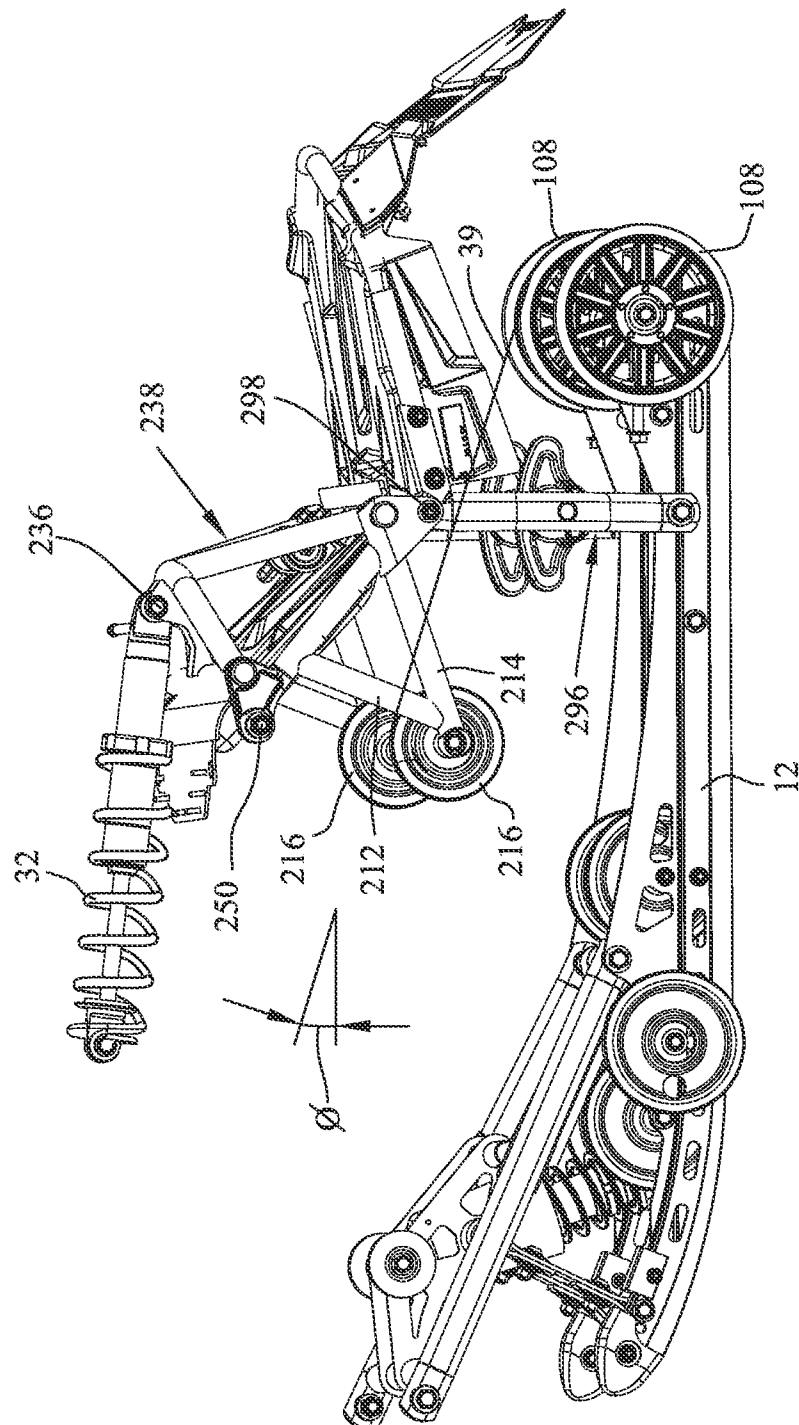


FIG. 27