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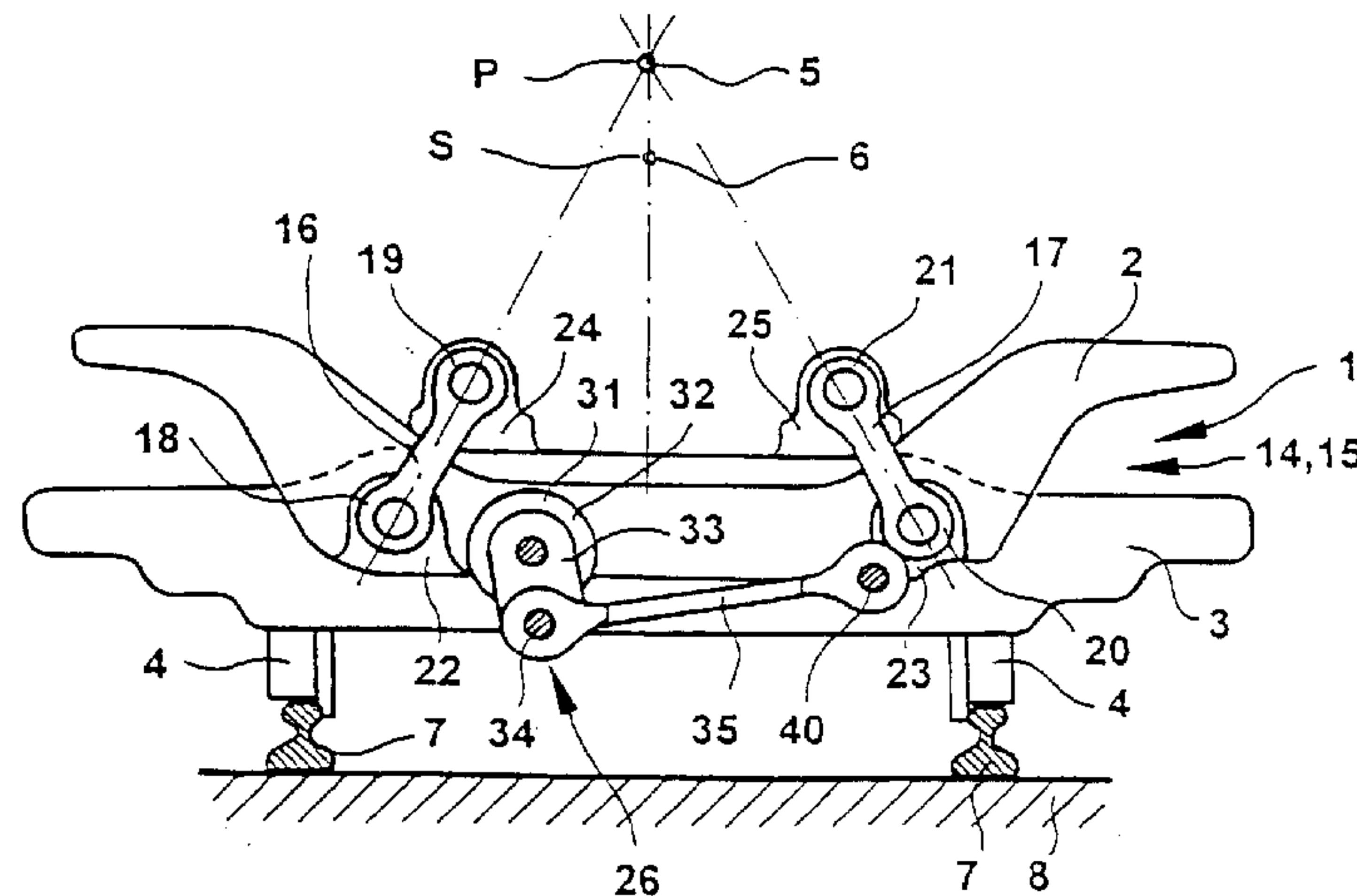
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(57) Abrégé/Abstract:

The invention refers to a tilting mechanism for creating track curve-dependent tilt of the superstructure of rail vehicles (1), consisting of a coupling means (15) with which the superstructure (2) is movably connected to a bogie (3) in such a way that the superstructure can be transferred from an upright initial position into a tilted position relative to the bogie and having a drive (31) and an adjusting means including a transfer means (33,34,35), by means of the adjusting means the superstructure can be movably transferred from its initial position into its tilted position relative to the bogie. To be able to manufacture such tilting mechanism in a more inexpensive way, the invention aims at equipping the transfer means with a gear with a variable transmission, the transmission of the gear (33,34,35) increasing with increasing inclination angle of the superstructure relative to the bogie during transfer of the superstructure from its initial position into its tilted position.

ABSTRACT

The invention refers to a tilting mechanism for creating track curve-dependent tilt of the superstructure of rail vehicles (1), consisting of a coupling means (15) with which the superstructure (2) is movably connected to a bogie (3) in such a way that the superstructure can be transferred from an upright initial position into a tilted position relative to the bogie and having a drive (31) and an adjusting means including a transfer means (33,34,35), by means of the adjusting means the superstructure can be movably transferred from its initial position into its tilted position relative to the bogie. To be able to manufacture such tilting mechanism in a more inexpensive way, the invention aims at equipping the transfer means with a gear with a variable transmission, the transmission of the gear (33,34,35) increasing with increasing inclination angle of the superstructure relative to the bogie during transfer of the superstructure from its initial position into its tilted position.

TILTING MECHANISM

The invention refers to a tilting mechanism for enabling curved track-dependent tilting of a superstructure of a rail vehicle, including a coupling means movably connecting the superstructure with a bogie in such a way that the superstructure can be brought from an upright initial position into a tilted position relative to the bogie and consisting of an adjusting means including a drive and a transfer means, the adjusting means rendering the superstructure movable for being transferred from its initial position into a tilted position relative to the superstructure.

Tilting mechanisms of such kind are known from the prior art. They are used in "tilting trains", as they are called. These are specially designed passenger trains, their design enabling the superstructure to be turned or "tilted" around its longitudinal axis, respectively, relative to a bogie. This tilting process aims at compensating the horizontal acceleration acting upon the passengers in curves. Despite a considerable improvement of cruising comfort for the passengers, the curved tracks can be passed much faster than allowed for normal trains by the EBO (German Rules for the Construction and Operation of rail vehicles), thus enabling the passengers to reach their destination much faster in case of winding railroad routes.

Such tilting mechanisms are subdivided into active and passive systems. Passive systems enable a tilting of the superstructure only as a result of centrifugal forces

acting upon the superstructure. The tilting angle of such systems is, however, very limited and amounts to a maximum of 1.2 up to 3.5 degrees, depending on the design. Active systems make use of an adjusting means by means of which the tilting between superstructure and bogie can be controlled via a control loop depending on the track curve and/or the velocity. These systems are generally suitable for a maximum inclination angle of approx. 8 degrees. The invention on file refers to such an active tilting mechanism.

In the case of known systems, the adjusting means either consists of a hydraulic servo cylinder or an electromechanical linear drive. The electromechanical linear drive, for example, is designed as a combination of an electromotor and a planet roller spindle. The adjusting means is located between the superstructure and the bogie.

It is known from the tilting trains in operation that an actuator force ranging from 8 to 10 tons is installed at each of the two bogies. Values this high are needed if the superstructure is to be held in its maximum excursion position of 8 degrees, since the center of gravity of the superstructure, in the case of large inclination angles, acts via a relatively large lever arm in the sense of a restoring torque. Forces this high are necessary to enable the superstructure to automatically return into its untilted initial position in case of a default of the tilting mechanism.

The design of the linear drive depends on the largest forces becoming active in case of a maximum angle of inclination. Furthermore, a relation between actuator force and the required torque at the motor exists for the known electromechanical actuators. In case of such a drive, it means that, for producing the necessary force, a current in the servo motor is necessary, its strength being also proportional to the angle of inclination. Since it is known that the stray power in a motor increases with the square of the engine current, this results in a considerably high stray power if the superstructure inclination is moving at high excursion angles.

This leads to the fact that the electromotor as well as the power electronics supplying it with electricity have to be designed for high levels of permanent power, naturally influencing the cost of acquisition of the mechanism.

Furthermore, the dimensions of the drive have a major influence on the required space of installation. In case of larger drive motors, this installation space has to be sufficiently large.

The invention is based on the object to create an actuator for the track curve-dependent control of the superstructure not characterized by the disadvantages described above with respect to the stray power occurring during operation at large inclination angles and being additionally designed in a more compact and cost-efficient way.

This object on which the invention is based is solved in that the transfer means consists of a gear with a variable transmission, the transmission of the drive increasing with increasing angle of inclination of the superstructure relative to the bogie when transferring the superstructure from its initial position into a tilted position.

This solution is simple and has the advantage that a larger transmission is provided in case of increasing inclination forces, thus making a considerably smaller dimensioned drive sufficient to cope with larger forces. Consequently, the transmission is lower in case of smaller angles of inclination and increases with increasing angles of inclination. A smaller transmission at smaller angles of inclination is desirable, thus reducing the gear losses and enabling the small actuator forces to safely bring the superstructure into the untilted initial position. Since a smaller drive with respect to the required permanent power is sufficient at comparable forces based on the angle of inclination, this has an influence on the drive itself as well as on the power electronics and the wiring, thus enabling a more inexpensive design of the tilting mechanism. A smaller drive also requires less installation space.

In one of its aspects, the present invention provides, in a tilting mechanism of a rail vehicle having a superstructure, for creating a track curve-dependent tilting of said superstructure, said tilting mechanism including a coupling means to which said superstructure and a bogie are movably connected such that said superstructure can be transferred from a mainly upright initial position to a tilted position relative to said bogie, an adjustment means by which said superstructure can be transferred from said initial position to said tilted position, said adjustment means having a transfer means and a drive, the improvement comprising: said transfer means including a force transfer mechanism having a variable displacement transmission ratio, whereby said displacement transmission ratio increases with an increase in the inclination angle of said superstructure relative to said bogie when said superstructure is transferred from said initial position to said tilted position.

In an advantageous development of the invention, the gear could include a crank mechanism with a crankshaft, consisting of a crank pin being displaced radially to the crankshaft and a drawbar and/or side rod pivotally connected to the crank pin. With such a gear a considerable transmission ratio can be easily realized for

variable gear ratios. In particular in case of an almost aligned crank mechanism, almost any large transmission can be realized.

The advantage resulting from a high gear transmission at large angles of inclination has a major effect on electromotor drives withstanding large actuator forces. In case of electromotor drives, the stray power is mainly influenced by the transmission of engine torques and not by the adjusting velocity as is the case with hydraulic linear actuators. On the other hand, electromotors are also considered to have an advantage over hydraulic or pneumatic drive units in that they need not be maintained so often, are easily available, have lower life cycle cost, are more easily mountable and consume less energy, thus being very environment-friendly.

Moreover, the gear between crank mechanism and motor can be of the reduction type. This results in that even smaller electromotors create the necessary tractive forces and/or transverse forces to bring the superstructure from its initial position into its tilted position.

It can be advantageous to connect the motor with the reduction gear and/or crank mechanism by means of an universal joint. In doing so, the electromotor can be installed in a more advantageous position, thus enabling a more compact design of the tilting mechanism.

As an alternative, the motor could also be connected to the reduction gear and/or to the crank mechanism by means of a belt drive or chain drive. Also in this case the tilting mechanism can be designed in a compact way by installing the motor in a suitable space distant from the reducing gear.

In case of an advantageous development of the invention, a line through the center of the crankshaft and the crank pin and a line through the center of the crank pin and the position of the bearing of the drawbar and/or side rod located distant to the crank pin can basically form a right angle in the initial position of the superstructure. This results in a particularly favorable force progression when initially bringing the superstructure from its initial position into a tilted position.

Extremely large inclination forces can be obtained if the crank mechanism is almost straight at a maximum inclination angle.

In the following, the invention is explained in detail by means of an embodiment:

The following figures show:

Fig. 1 a schematic view of the tilting mechanism on which the invention is based, showing the superstructure in its initial position;

Fig. 2 a tilting mechanism according to Fig. 1 in which the superstructure is in a tilted position;

Fig. 3 the same view as in Fig. 2, the superstructure, however, being tilted in the opposite direction compared to Fig. 2;

Fig. 4 a schematic view of the adjusting means;

Fig. 5 a horizontal projection of the adjusting means from Fig. 4;

Fig. 6 an alternative embodiment of the adjusting means in the same projection as in Fig. 5;

Fig. 7 an alternative embodiment of the adjusting means in the same projection as in Fig. 5

Fig. 8a a diagram showing the progression of the torque relative to the angle of inclination;

Fig. 8b a diagram showing the transmission relative to the turning angle of the crank;

Fig. 9 tilting mechanism known from the prior art;

Fig. 10 a tilting mechanism known from the prior art;

Fig. 11 another tilting mechanism known from the prior art.

Fig. 9 shows a cross section through a passenger train 1, or a track vehicle, respectively, with a superstructure 2 and a bogie 3. The bogie 3 includes track wheels 4 being linked to one another by an axis 5 and running in bearings 6 of the bogie 3. The track wheels 4 are running on schematically shown tracks 7 attached to a base 8.

The superstructure 2 includes an interior space 9 in which seats 10 are arranged. A person 11 is shown in schematic view sitting on one of the seats 10.

The superstructure 2 consists of a secondary suspension system 12, the suspension elements of which are shown in schematic view. The suspension system 12 is arranged between the superstructure 2 and a carrier element 13 belonging to the superstructure 2. Instead of a suspension system 12, the carrier element 13 may be directly and rigidly connected to superstructure 2 or be part of the superstructure 2, respectively.

A tilting mechanism 14 is located between superstructure 2 and bogie 3. This tilting mechanism includes a coupling means 15, mainly consisting of a four-bar-mechanism. The four-bar-mechanism is formed by joint rods 16 and 17, each joint rod having ends 18 and 19 and 20 and 21, respectively. These ends form bearing positions. Each end 18 to 21 is pivotably located in swivel fixed pivot brackets 22 to 25, the swivel fixed pivot brackets 22 and 23 being mounted onto the superstructure 2 and each swivel fixed pivot bracket 24 and 25 being fixedly mounted onto the bogie 3.

The swivel fixed pivot brackets 22 to 25 are arranged in such a way that the ends 18 and 20 of the joint rods 16 and 17 are located further apart from one another than the ends 19 and 21 of the joint rods 16 and 17. Also the swivel fixed pivot brackets 22 and 23 of the superstructure are arranged underneath the swivel fixed pivot

brackets 24 and 25 of the bogie, thus forming a four-bar-mechanism allowing the superstructure 2 to be pivoted relative to the bogie 3.

The center of gravity S of the superstructure 2 is located underneath the rotation axis P of the four-bar-mechanism. This enables the superstructure 2 to automatically stabilize itself in a initial position in which it is mainly vertically arranged on the bogie 3. In Fig. 9, the superstructure 2 is tilted at an inclination angle α relative to the bogie 3 or is in its tilted position, respectively. The maximum inclination angle α amounts to approx. 8° as shown in the embodiment on file.

An adjusting means 26 is located between bogie 3 and the superstructure 2, or several adjusting means 26 can be present, respectively. This adjusting means 26 supports itself on superstructure 2 and bogie 3.

In the prior art depicted in Fig. 9, this adjusting means consists of hydraulic cylinders 27 and 28. By means of respective expansion or shortening of the hydraulic cylinder, the superstructure 2 can be tilted relative to the bogie 3.

A second embodiment taken from the prior art is depicted in Fig. 10 in which hydraulic cylinders 27 and 28 serve as an adjusting means 26 as well. In contrast to the first embodiment from the prior art, the secondary suspension system 12 is arranged on the bogie 3, the carrier element 13 this time supporting itself on the axis bearings 6.

In a third embodiment (Fig. 11) of the prior art, electric linear actuators 29 and 30 are being used instead of hydraulic cylinders. By expanding or shortening of the actuators 29 and 30, adjusting or tilting, respectively, of the superstructure 2 relative to the bogie is made possible.

In case of the solution corresponding to the invention, the functioning of which being clearly depicted in Fig. 1 to 3, the suspension system 12 is not illustrated for reasons of clarity. In case of the embodiment corresponding to the invention, the hydraulic cylinders 27 and 28 and the linear actuators 29 and 30, respectively, are replaced by an electromotor 31, consisting of a reduction gear 32 with a crankshaft 33. The

crankshaft 33 includes a crank pin 34 on which a drawbar and/or side rod 35 is pivotably fixed, thus forming a gear with an infinitely variable transmission. The electromotor 31 with the reducing gear 32 is attached to the bogie 3. The other end of the drawbar and/or side rod 35 is pivotably connected to the superstructure 2.

Fig. 5 shows a top view of the adjusting means 26, the crankshaft being pivotably supported by the reduction gear 32 on the one hand and by a swivel fixed pivot bracket 39 on the other hand, the swivel fixed pivot bracket 39 not being shown in detail for reasons of clarity in Fig. 1 to 3. In alternative embodiments, the electromotor 31 may be connected to the reduction gear 32 either by means of an universal joint 37 or a belt drive 38 as shown in Fig. 6 and 7.

The drawbar and/or side rod 35 is jointly connected with the superstructure 2 via a swivel fixed pivot bracket and a crank pin 40.

The superstructure 2 is only schematically shown in Fig. 1 to 3, wherein a carrier element 13 is shown as a substitute for the superstructure 2, the superstructure 2 being mounted onto the carrier element 13 which may also be part of the superstructure 2.

In an initial position the adjusting means 26 is preset in such a way that a line through the center of the crankshaft 33 and the crank pin 34 forms a more or less right angle together with a line through the crank pin 34 and the journal of the shaft 40. In a state of maximum excursion or tilting of the superstructure 2 relative to the bogie 3, respectively, the adjusting means 26 or the crank mechanism, respectively, is mainly aligned as can be seen from Fig. 3 and Fig. 2. Controlling of the adjusting means 26 is made possible in the invention by a control device 41, by means of which the turning direction of the electromotor 31 can be controlled depending on the desired excursion. The maximum excursion value amounts to approx. 8 degrees as characterized by the angle α in Fig. 2.

In the following, the mode of operation as well as the way of functioning is described in detail:

In the initial position of the superstructure 2 relative to the bogie 3, the superstructure 2 is arranged more or less upright on the bogie 3. The superstructure 2 is in its initial position when cruising straight forward. In case the passenger train 1 enters a curve, the superstructure 2 relative to the bogie 3, may be infinitely tilted to a respective angle α depending on cruising velocity and radius of the curve towards the interior of the curve. Such a tilt for the superstructures is for example shown in Fig. 9 to 11. To reach such a tilt, the electromotor 31 is activated via the control device 41, thus transferring a turning movement of the motor shaft not depicted here by means of the reduction gear 32 to the crankshaft 33 which changes its initial state shown in Fig. 1 to a state depicted in Fig. 2 or 3, depending on the desired direction of inclination. A turning of the crankshaft 33 results in that the drawbar and/or side bar 35 exerts a force on the carrier element 13 or the superstructure 2, respectively, causing it to tilt by the desired angle α relative to the bogie 3.

During initial excursion, the electromotor 31 requires a relatively low torque which progressively increases to a maximum value with increasing rotation of the crankshaft 33, followed by a later decrease. Close to the maximum excursion of the superstructure 2 relative to the bogie 3, the motor torque decreases despite increasing excursion forces due to the kinematic arrangement of crankshaft 33 and drawbar and/or side bar 35. The torque progression is schematically shown in Fig 8a, the transmission ratio of motor torque angle relative to the inclination of the superstructure depending on the crank angles can be seen in Fig 8b. The motor torque or the transmission ratio, respectively, is shown as a norm, since it changes according to the size of the superstructure 2 and other design factors. Important is only the progression of the motor torque at which a very low motor torque is necessary during maximum excursion. This aspect of the invention represents a major difference to conventional solutions in which the motor of the linear drive has to create a maximum torque in case of maximum angles of inclination.

The novel design of the tilting mechanism now enables tilting systems for predetermined loads to be equipped with electromotors with lower permanent output. The tilting mechanism on which the invention is based can be manufactured more inexpensively and can be designed for smaller spaces. It is also possible to displace the electromotor 31 relative to the reduction gear or the crankshaft 33 by including a

universal joint 37 or a belt drive 38, respectively. This enables the tilting mechanism to be adjusted to the given installation situation in the bogie 3.

We Claim:

1. Tilting mechanism for creating a track curve-dependent tilt of a superstructure of rail vehicles (1), including a coupling means (15) to which the superstructure (2) with a bogie (3) is movably connected in such a way that the superstructure can be transferred from a mainly upright initial position into a tilted position relative to the bogie and having a drive (31) and an adjustment means including a transfer means (33,34,35) by means of the adjustment means the superstructure can be transferred from its initial position into a tilted position relative to the bogie, characterized in that the transfer means includes a gear (33, 34,35) having a variable transmission, the transmission of the gear increases when the superstructure is transferred from its initial position into its tilted position with increasing inclination angle of the superstructure relative to the bogie.
2. Tilting mechanism according to claim 1, characterized in that the gear includes a crank mechanism (33,34,35) with a crankshaft (33) being equipped with a crank pin (34) radially displaced relative to the crankshaft, a drawbar or side bar (35) being pivotably attached to the crank pin (34).
3. Tilting mechanism according to claim 1, characterized in that the drive comprises an electromotor (31).
4. Tilting mechanism according to claim 2, characterized in that the drive comprises an electromotor (31).
5. Tilting mechanism according to claim 4, characterized in that the electromotor (31) is attached to the bogie (3), and

the drawbar or side bar (35) is attached to the superstructure (2).

6. Tilting mechanism according to claim 4, characterized in that the electromotor is linked to the superstructure (2), and the drawbar or side bar is linked to the bogie (3).

7. Tilting mechanism according to any one of claims 2, 4, 5, or 6, characterized in that the gear includes a reduction gear (32) between the crank mechanism and drive.

8. Tilting mechanism according to claim 7, characterized in that the drive is connected to the reduction gear and the crank mechanism by means of a universal joint (37).

9. Tilting mechanism according to claim 7, characterized in that the drive is connected to the reduction gear or the crank mechanism by means of a universal joint (37).

10. Tilting mechanism according to claim 7, characterized in that the drive is connected to the reduction gear and the crank mechanism by means of a belt drive or chain drive (38).

11. Tilting mechanism according to claim 7, characterized in that the drive is connected to the reduction gear or the crank mechanism by means of a belt drive or chain drive (38).

12. Tilting mechanism according to any one of claims 2, 4, 5, 6, 7, 8, 9, 10, or 11, characterized in that in the initial position of the superstructure, a line through the center of the crankshaft and the crank pin forms a right angle to a large

extent with the line through the center of the crank pin and a bearing position of the drawbar or side bar located distant to the crank pin.

13. Tilting mechanism according to any one of claims 2, 4, 5, 6, 7, 8, 9, 10, 11, or 12, characterized in that the crank mechanism is aligned to a large extent in case of a maximum inclination angle.

14. Tilting mechanism according to claim 1, characterized in that the gear includes a crank mechanism (33,34,35) with a crankshaft (33) being equipped with a crank pin (34) radially displaced relative to the crankshaft, a drawbar and side bar (35) being pivotably attached to the crank pin (34).

15. Tilting mechanism according to claim 14, characterized in that the drive comprises an electromotor (31).

16. Tilting mechanism according to claim 15, characterized in that the electromotor (31) is attached to the bogie (3), and the drawbar and side bar (35) is attached to the superstructure (2).

17. Tilting mechanism according to claim 15, characterized in that the electromotor is linked to the superstructure (2), and the drawbar and side bar is linked to the bogie (3).

18. Tilting mechanism according to any one of claims 14, 15, 16, or 17, characterized in that the gear includes a reduction gear (32) between the crank mechanism and drive.

19. Tilting mechanism according to claim 18, characterized in that the drive is connected to the reduction gear and the crank mechanism by means of a universal joint (37).

20. Tilting mechanism according to claim 18, characterized in that the drive is connected to the reduction gear or the crank mechanism by means of a universal joint (37).

21. Tilting mechanism according to claim 18, characterized in that the drive is connected to the reduction gear and the crank mechanism by means of a belt drive or chain drive (38).

22. Tilting mechanism according to claim 18, characterized in that the drive is connected to the reduction gear or the crank mechanism by means of a belt drive or chain drive (38).

23. Tilting mechanism according to any one of claims 14 to 22, characterized in that in the initial position of the superstructure, a line through the center of the crankshaft and the crank pin forms a right angle to a large extent with the line through the center of the crank pin and a bearing position of the drawbar and side bar located distant to the crank pin.

24. Tilting mechanism according to any one of claims 14 to 23, characterized in that the crank mechanism is aligned to a large extent in case of a maximum inclination angle.

25. In a tilting mechanism of a rail vehicle (1) having a superstructure (2), for creating a track curve-dependent tilting of said superstructure, said tilting mechanism including a coupling means (15) to which said superstructure and a bogie (3) are movably connected such that said superstructure can be transferred from a mainly upright initial position to a tilted position relative to said bogie, an adjustment means (26) by which said superstructure can be transferred from said initial position to said tilted position, said adjustment means having a transfer means and a drive (31), the improvement comprising:

said transfer means including a force transfer mechanism having a variable displacement transmission ratio, whereby said displacement transmission ratio increases with an increase in the inclination angle of said superstructure relative to said bogie when said superstructure is transferred from said initial position to said tilted position.

26. The tilting mechanism as set forth in claim 25, wherein said force transfer mechanism includes a crankshaft (33), said crankshaft having a crank pin (34) radially displaced relative to said crankshaft, and a drawbar (35) pivotably attached to said crank pin (34).

27. The tilting mechanism as set forth in claim 26, wherein said crankshaft and said drawbar are substantially aligned at a maximum inclination angle.

28. The tilting mechanism as set forth in claim 26, wherein, at said initial position, a first line drawn through the center of said crankshaft and the said crank pin forms a substantially right angle with a second line drawn through the center of said crank pin and a bearing position of the drawbar located distant to said crank pin.

29. The tilting mechanism as set forth in claim 26, wherein said drive is an electromotor (31).

30. The tilting mechanism as set forth in claim 29, wherein said electromotor (31) is attached to said bogie (3), and said drawbar (35) is attached to said superstructure (2).
31. The tilting mechanism as set forth in claim 29, wherein said electromotor is attached to said superstructure (2), and said drawbar is attached to said bogie (3).
32. The tilting mechanism as set forth in claim 25, wherein said drive is an electromotor (31).
33. The tilting mechanism as set forth in claim 32, wherein said transfer means includes a reduction gear (32) between said force transfer mechanism and said electromotor.
34. The tilting mechanism as set forth in claim 33, wherein said electromotor is connected to said reduction gear by a universal joint (37).
35. The tilting mechanism as set forth in claim 33, wherein said electromotor is connected to said force transfer mechanism by a universal joint.
36. The tilting mechanism as set forth in claim 33, wherein said electromotor is connected to said reduction gear by a belt drive (38).
37. The tilting mechanism as set forth in claim 33, wherein said electromotor is connected to said reduction gear by a chain drive.

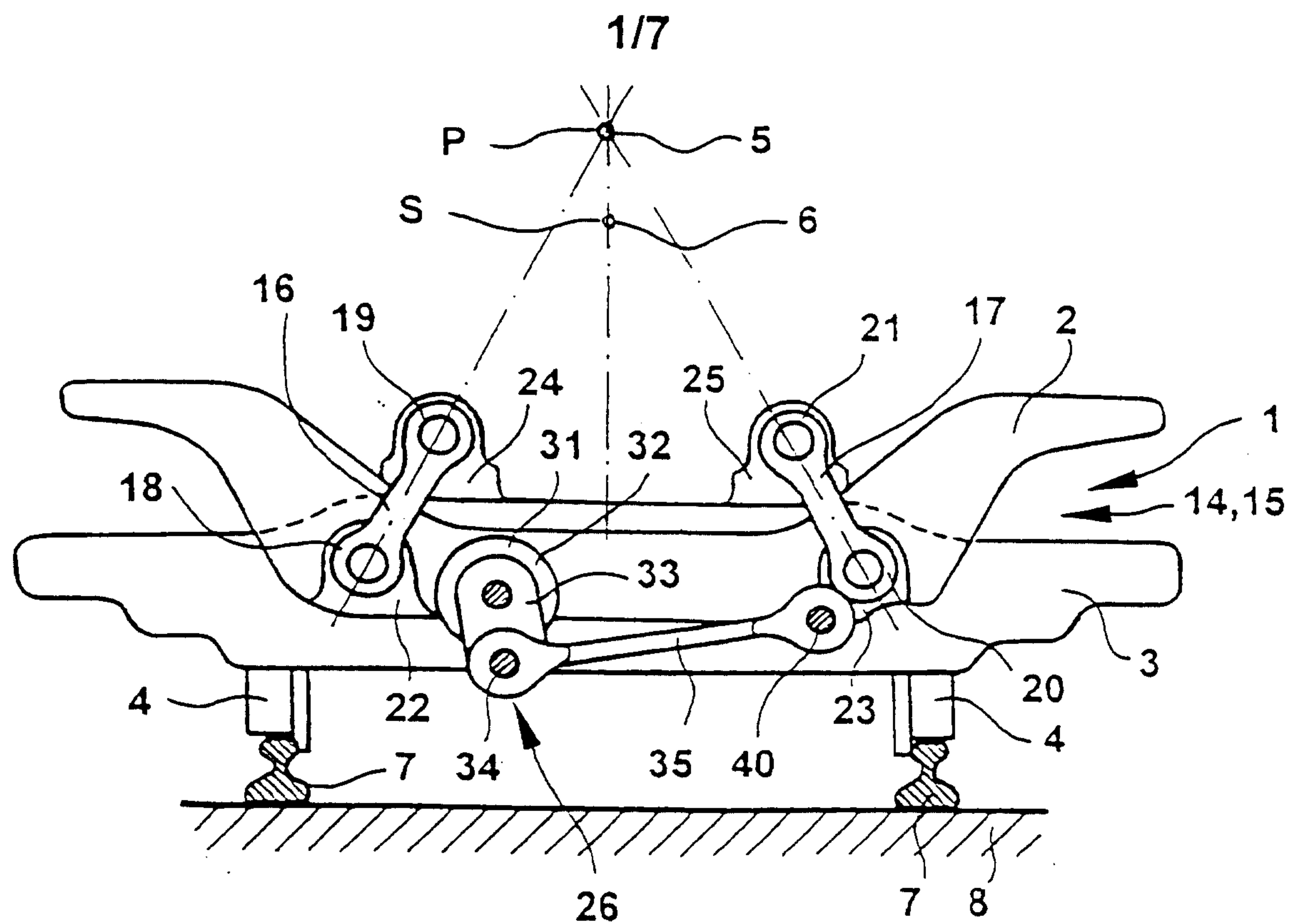


FIG. 1

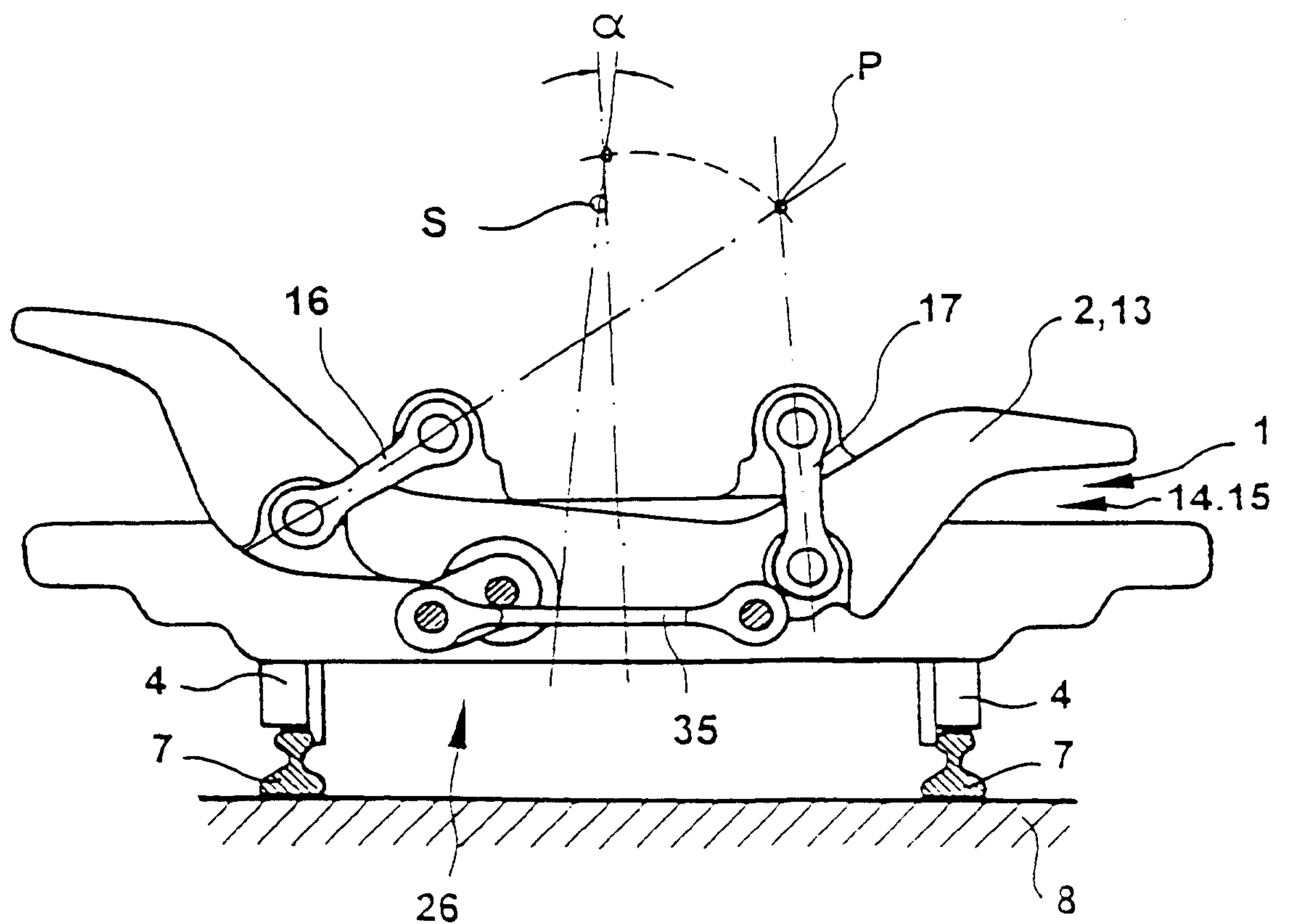


FIG. 2

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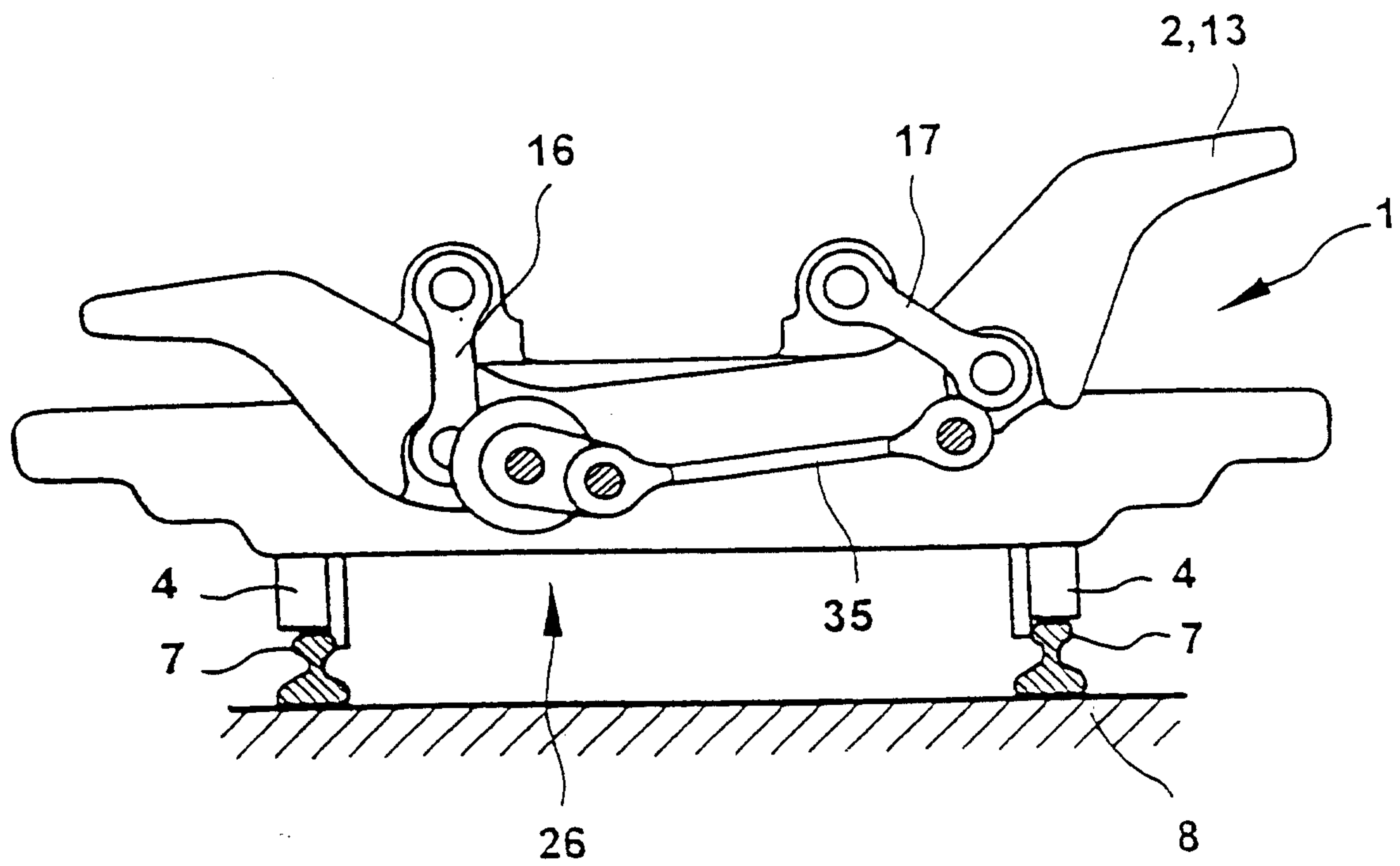


FIG. 3

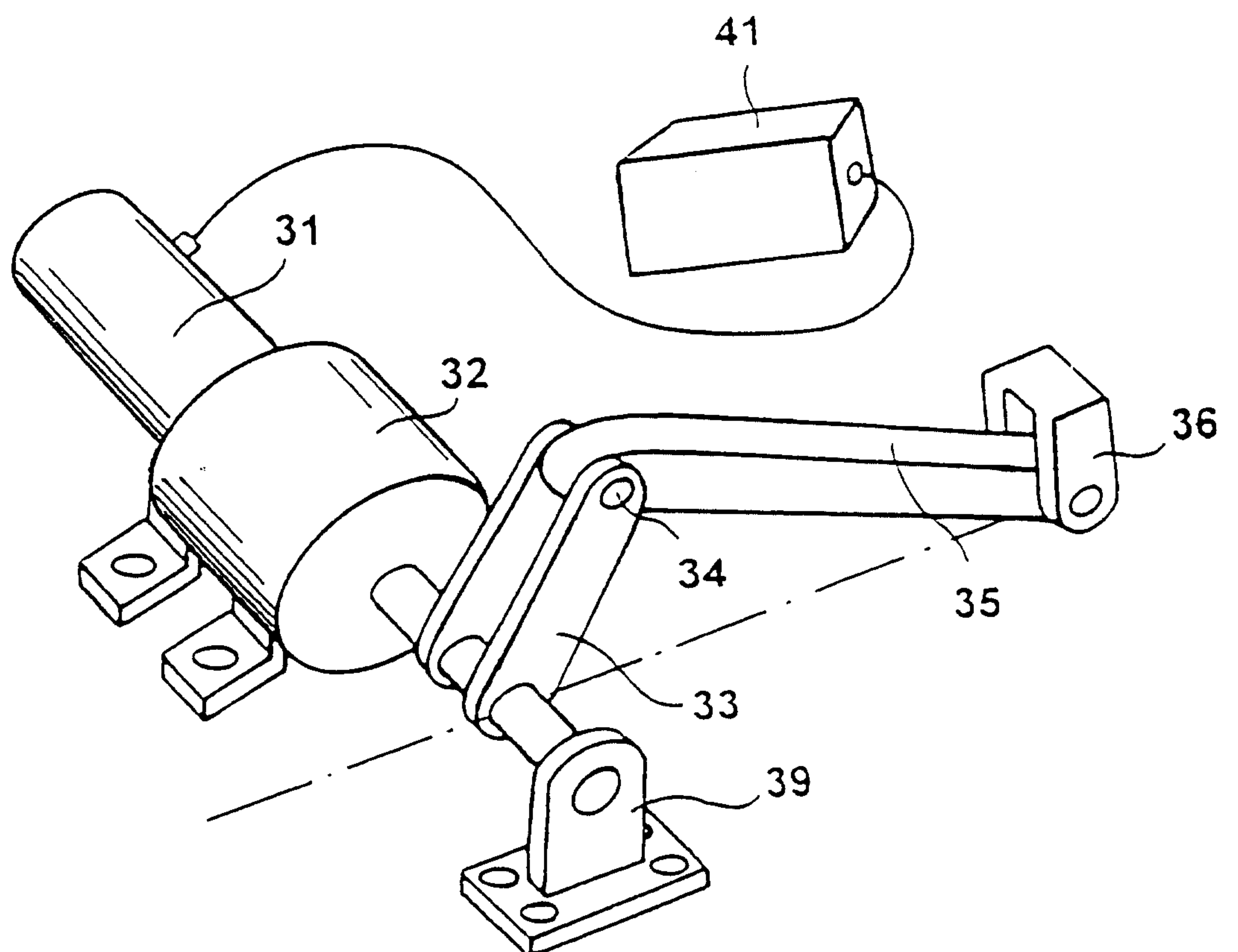


FIG. 4

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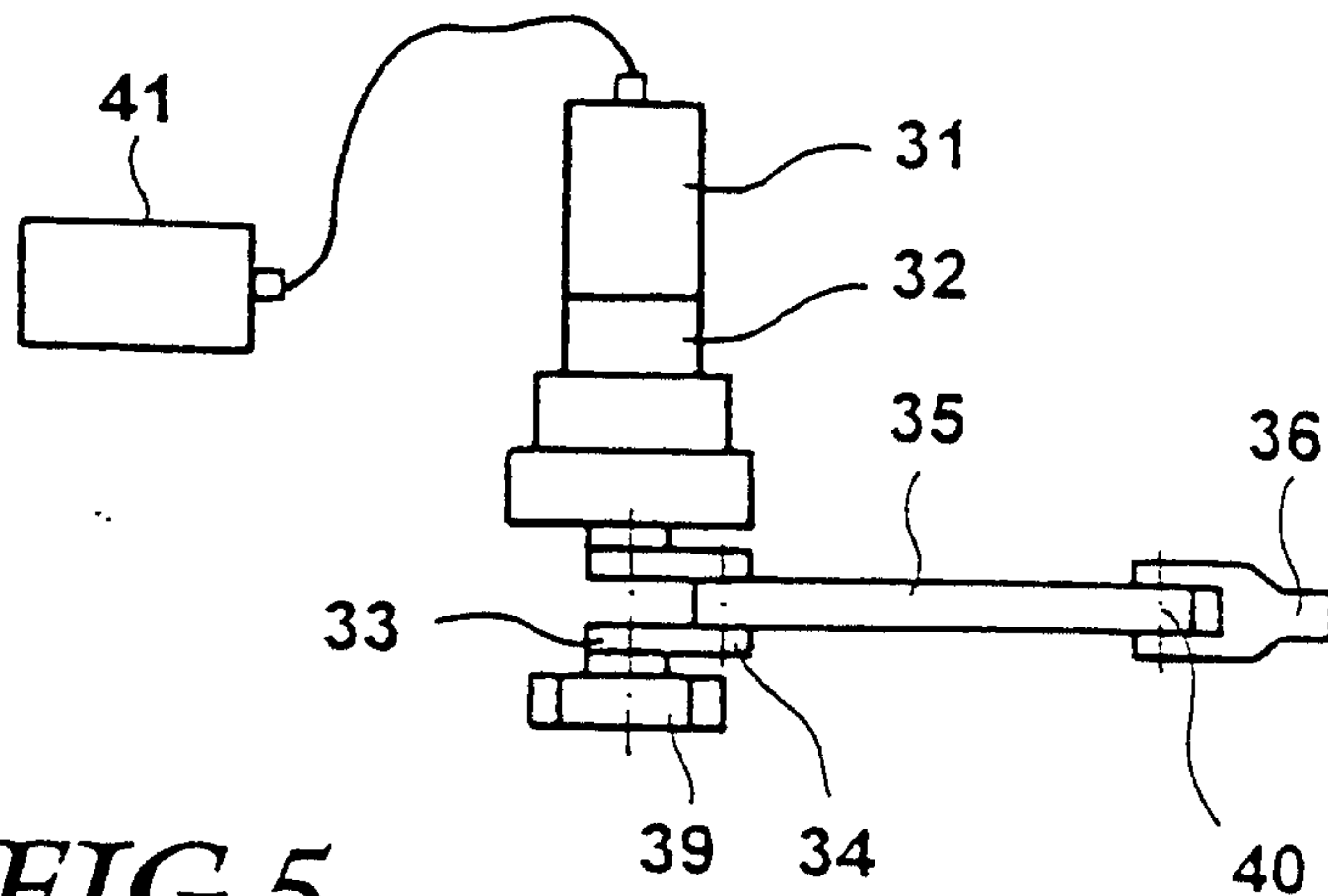


FIG. 5

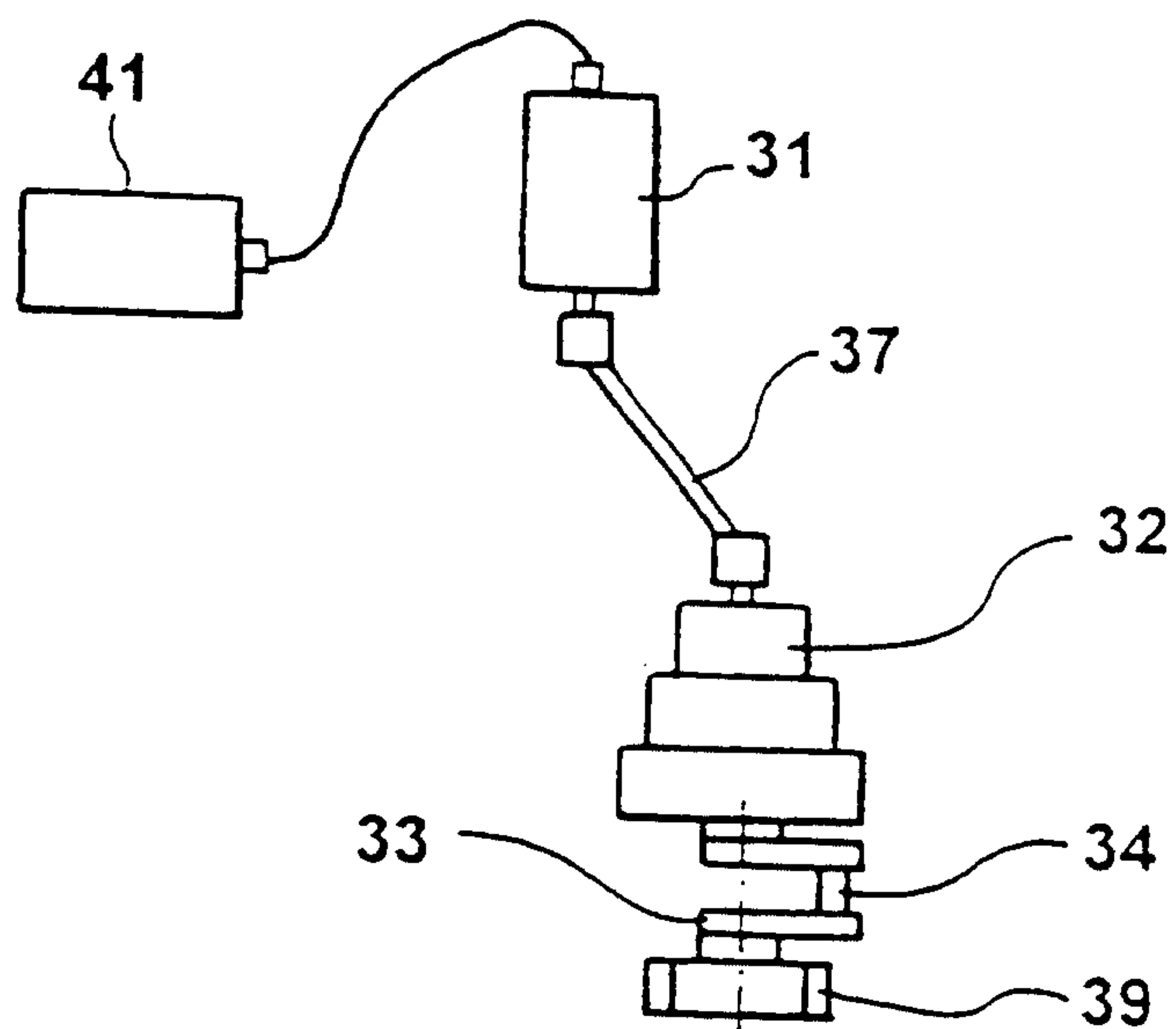


FIG. 6

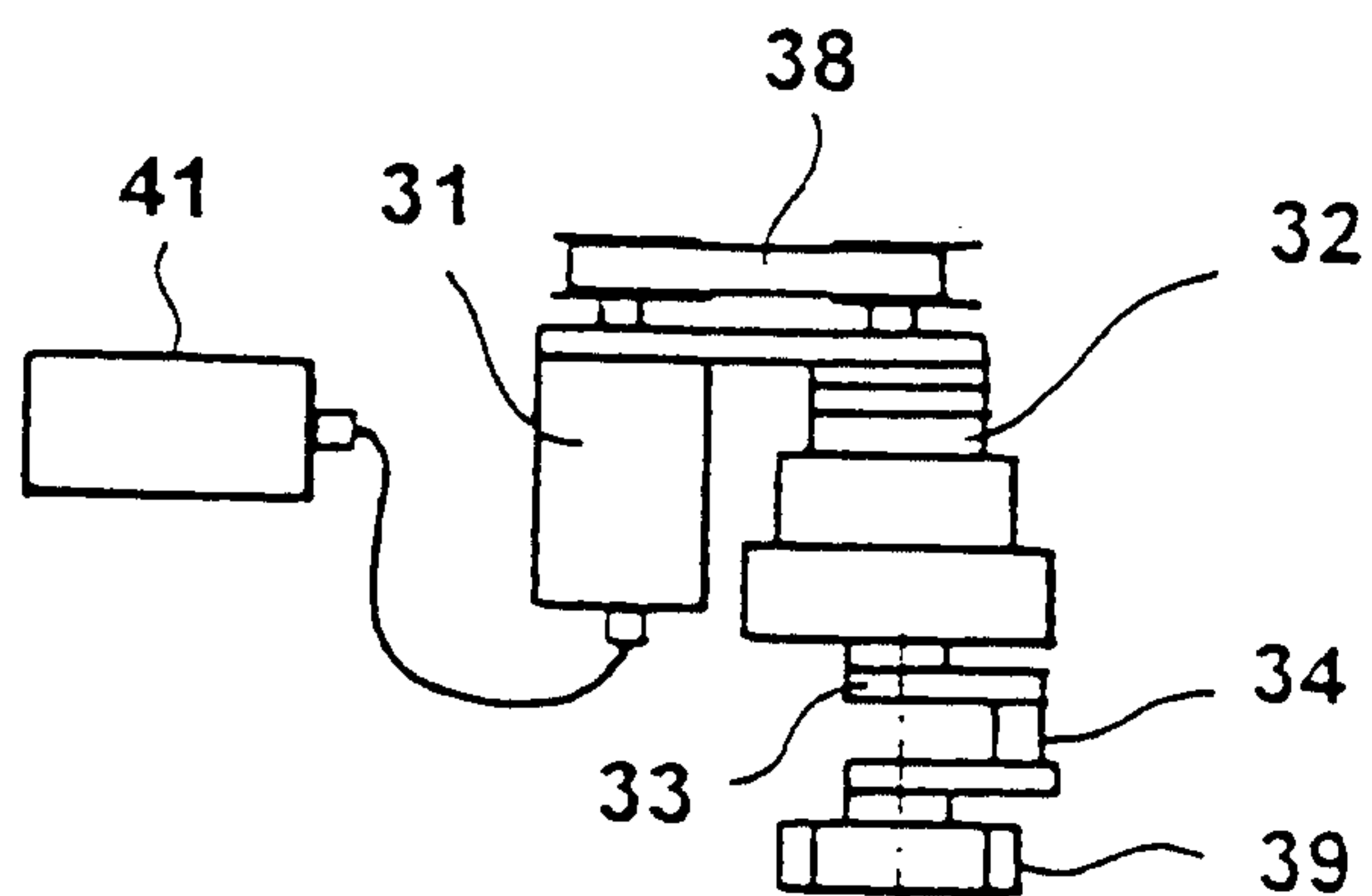
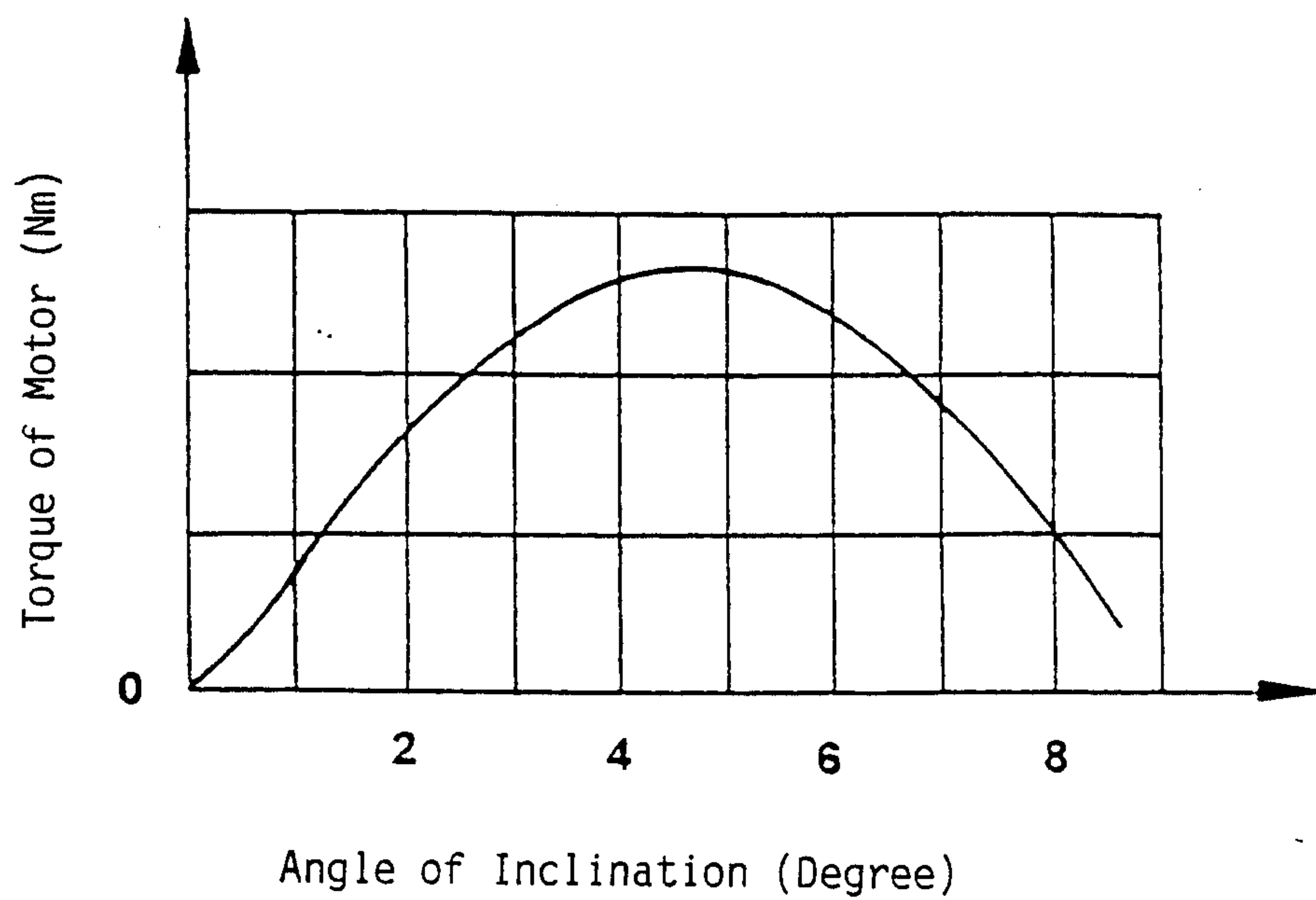
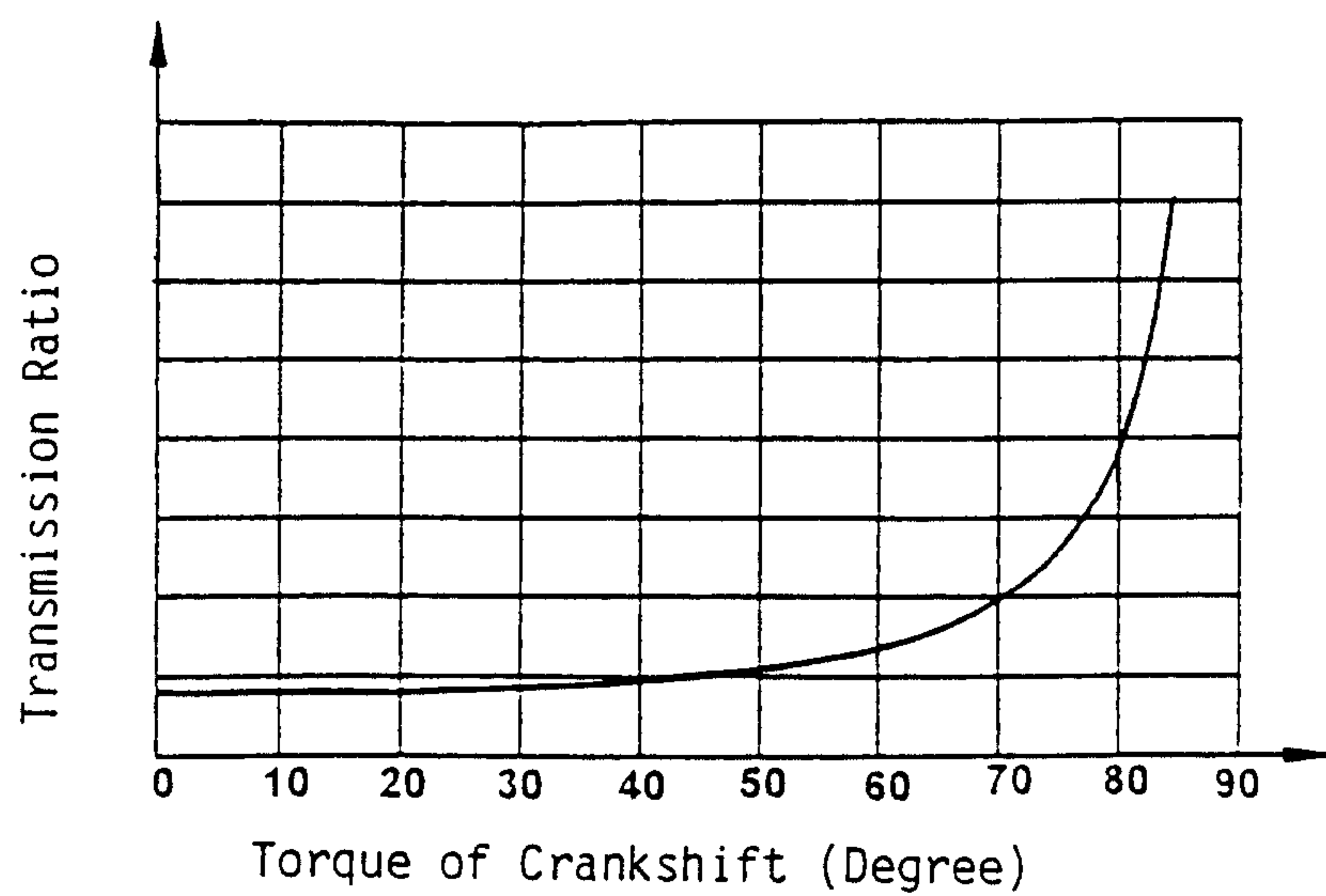
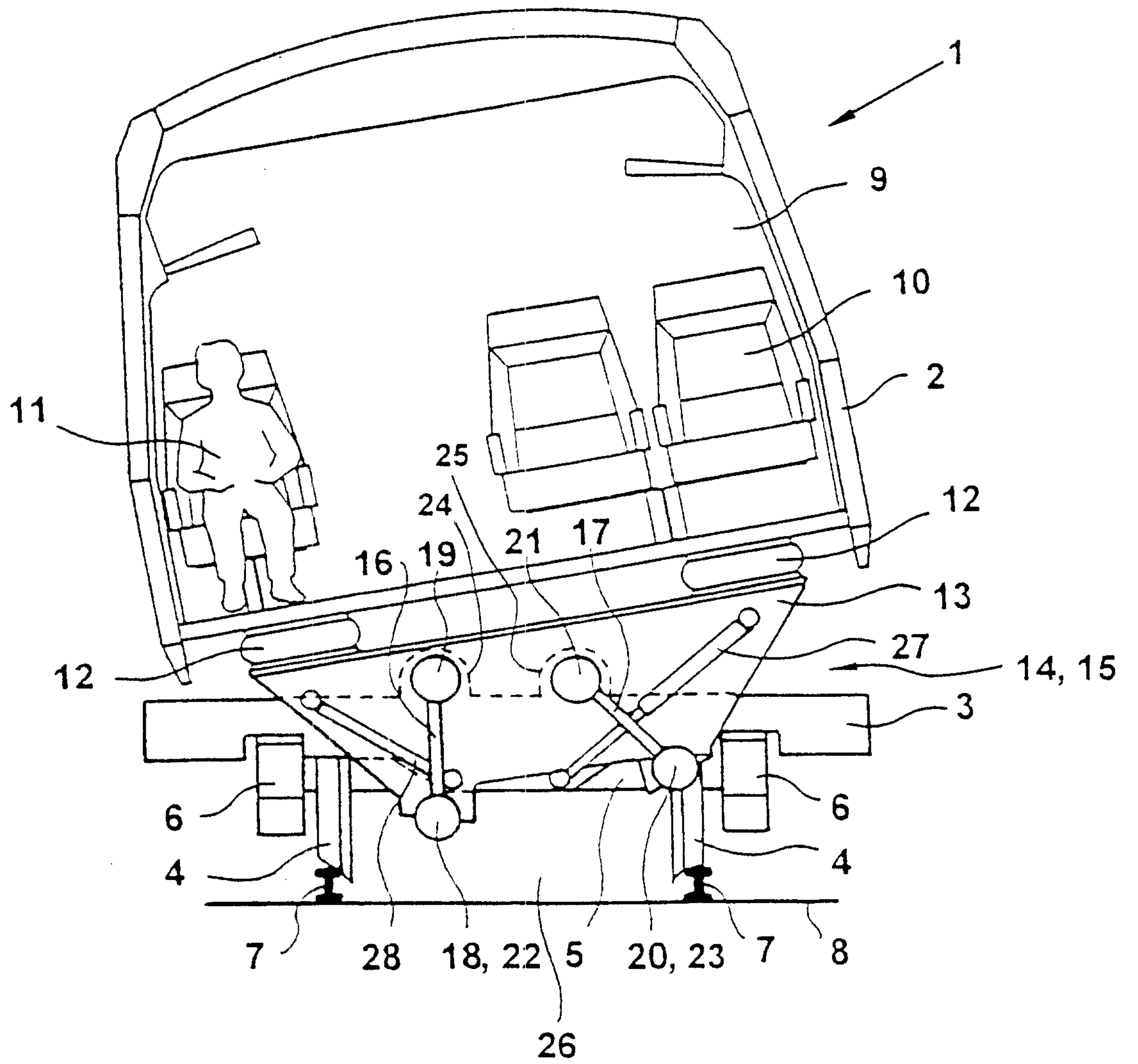


FIG. 7

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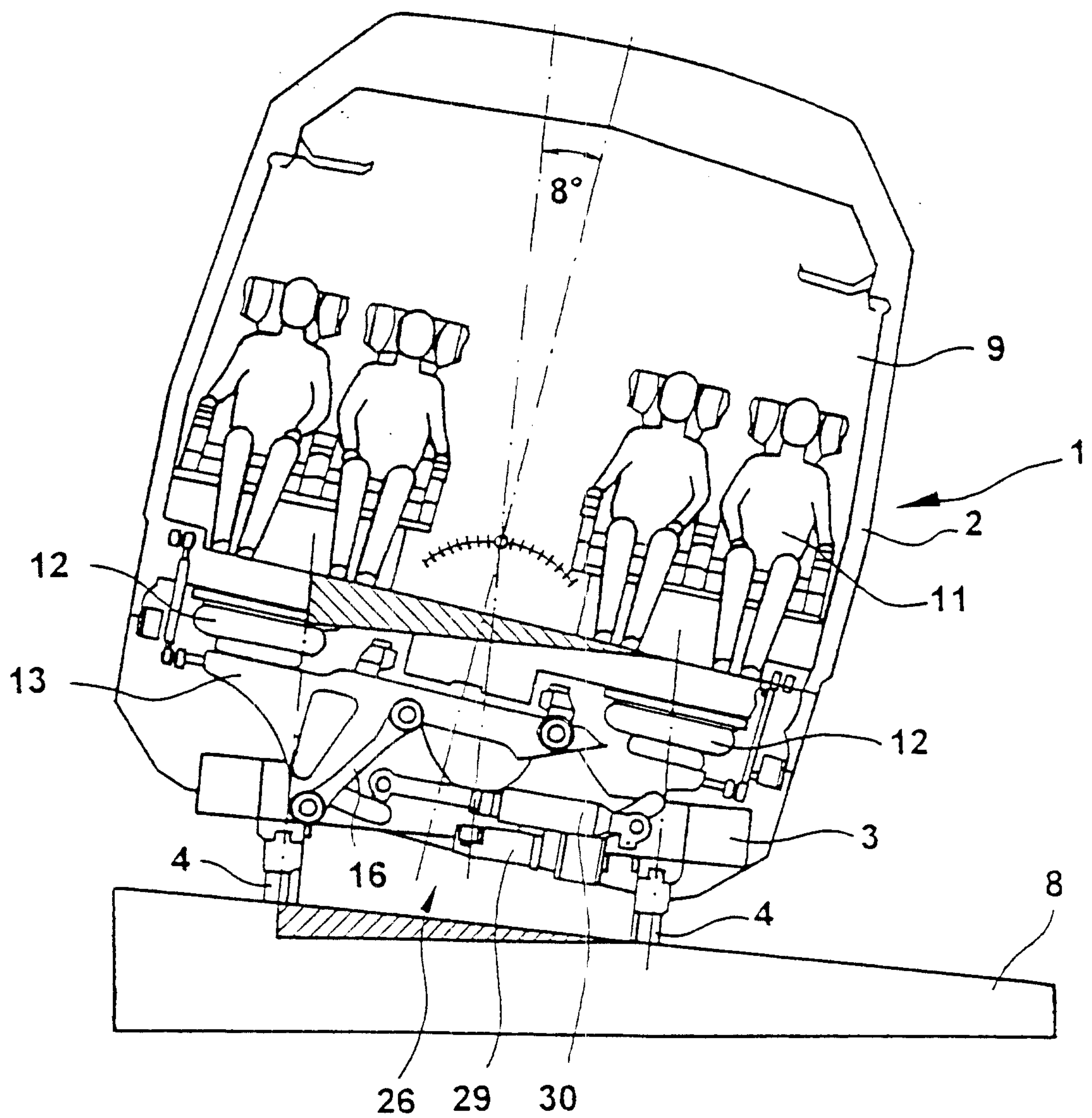
**FIG. 8a****FIG. 8b**

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*FIG. 9*

(PRIOR ART)

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*FIG. 11*

(PRIOR ART)

