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(54) **CONTINUOUSLY VARIABLE GEAR TRANSMISSION**

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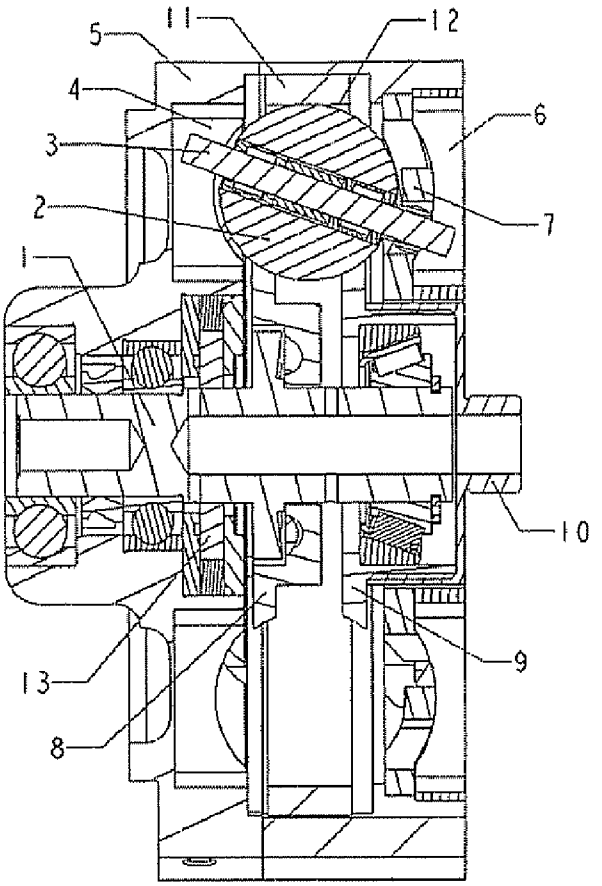
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(57) **ABSTRACT**

A continuously variable gear is described having an input shaft (**1**), a plurality of traction balls (**2**) distributed radially around the axis, each traction ball (**2**) is mounted on an axle (**3**) passing there through, the axles (**3**) are tiltable in the radial grooves (**4**) in the housing (**5**) and support plate (**6**), To control the position of the traction bails (**2**), the axles are guided in curved slots (**13**) of turnable iris plate (**7**). To control the axial placement of the traction balls (**2**), there is a rotatable input disc (**8**) positioned adjacent to the traction balls (**2**), a rotatable output disc (**9**) positioned adjacent to the traction balls (**2**) opposite the input disc (**8**), and a pre-spanning ring around the traction balls (**2**) such that each of the traction balls (**2**) is making three-point contact with the input disc (**8**), the output disc (**9**) and the pre-spanning ring (**11**), the contact surface of the pre-spanning ring (**11**) having a specific curvature larger than the radius of the traction balls (**2**).



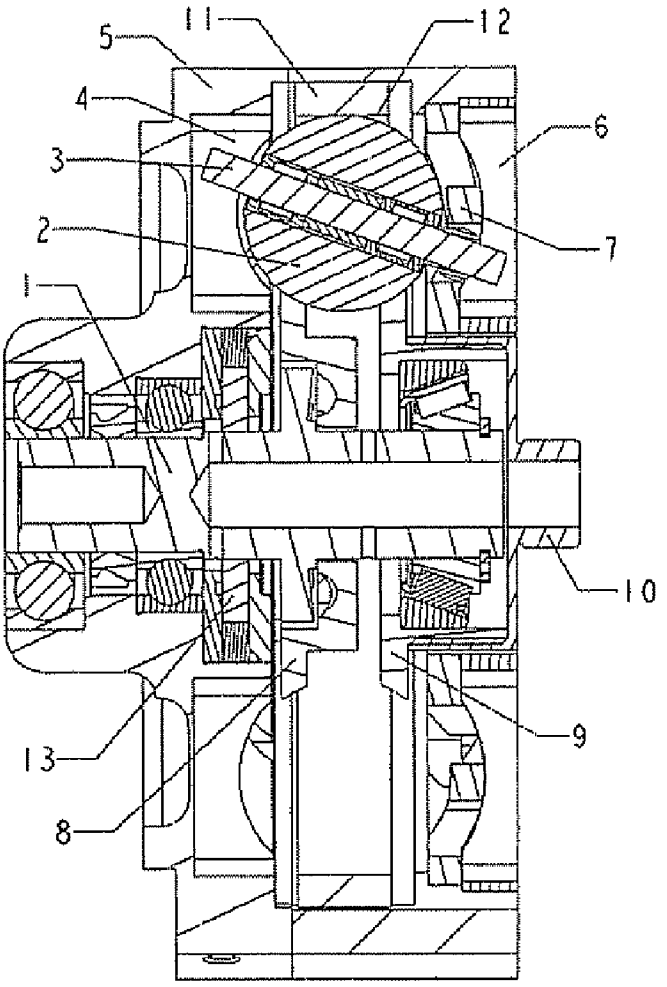


FIG. 1

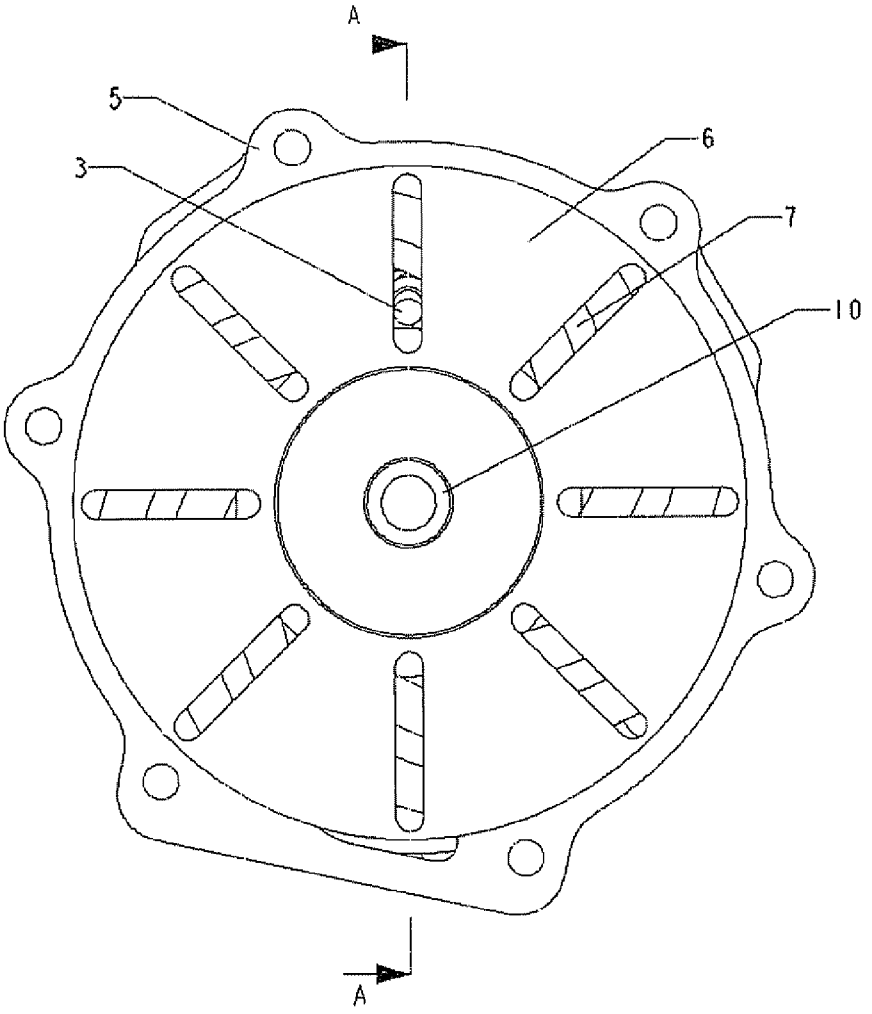


FIG. 2

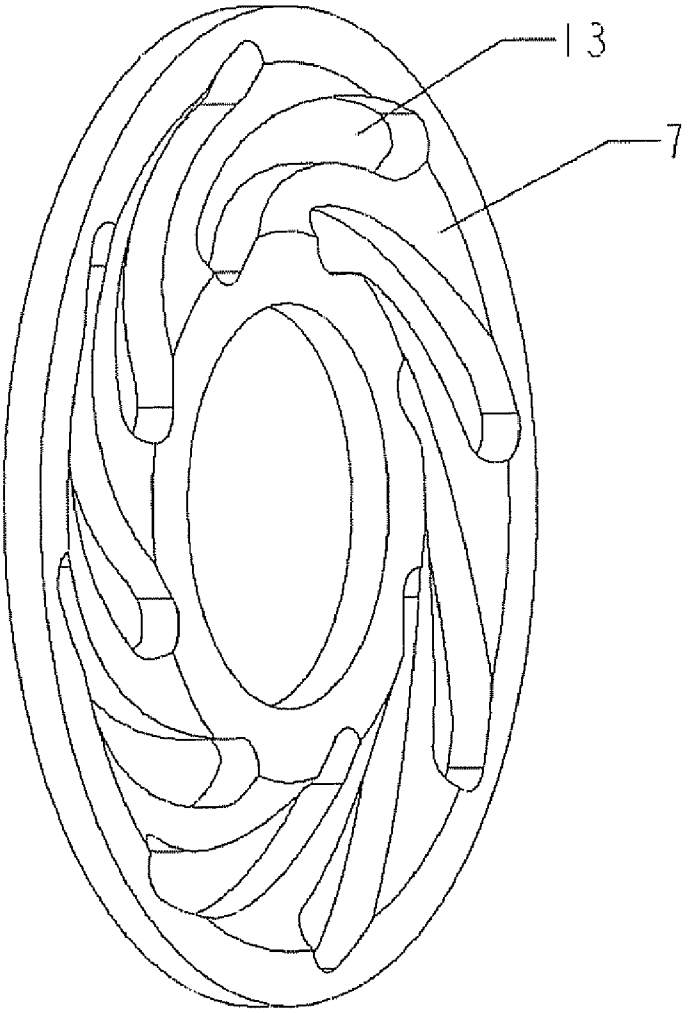


FIG. 3

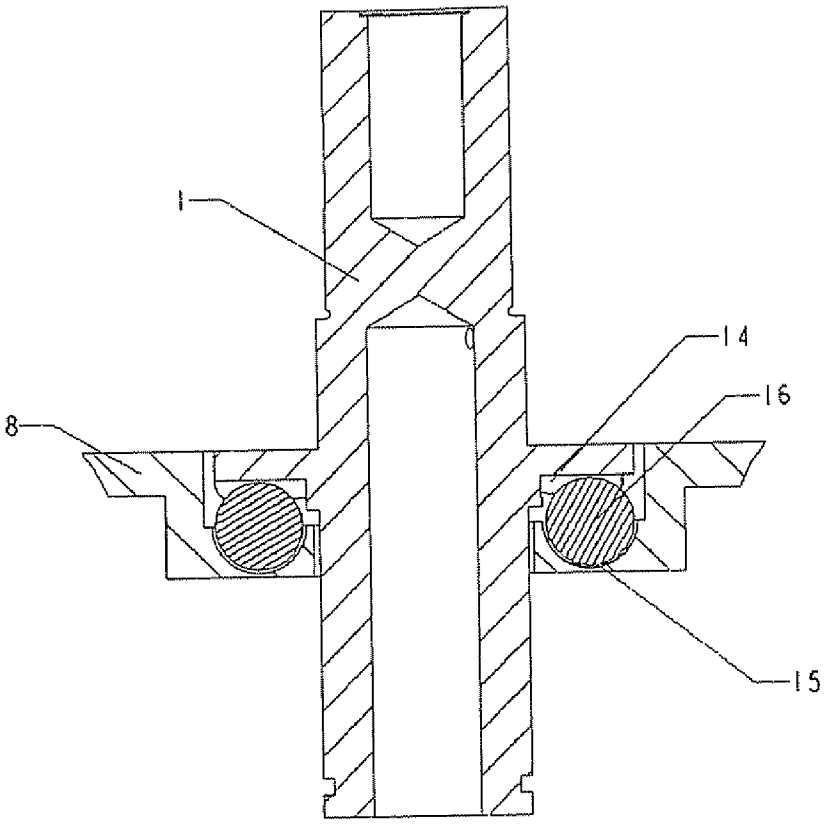


FIG. 4A

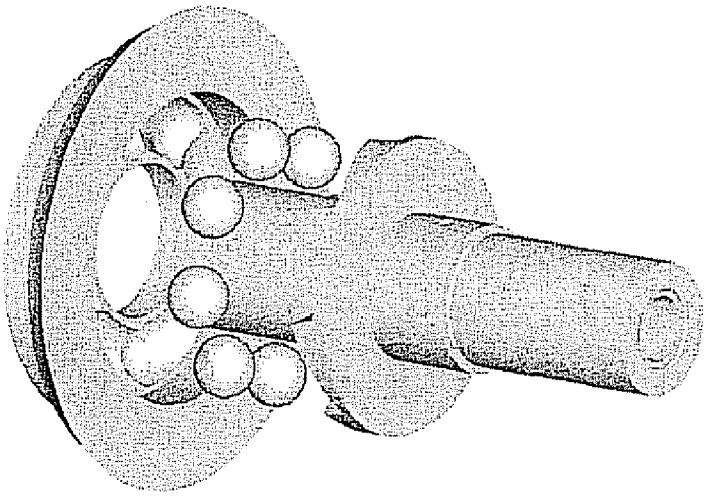


FIG. 4B (for illustrative purposes only)

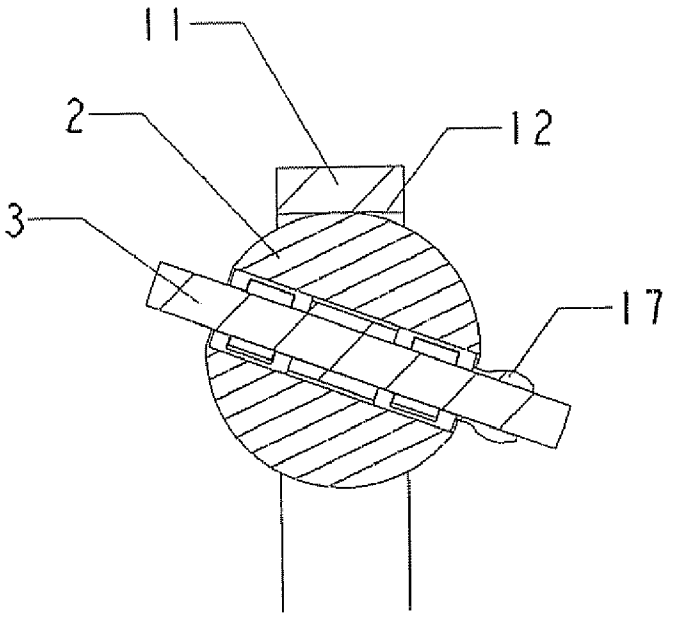


FIG. 5A

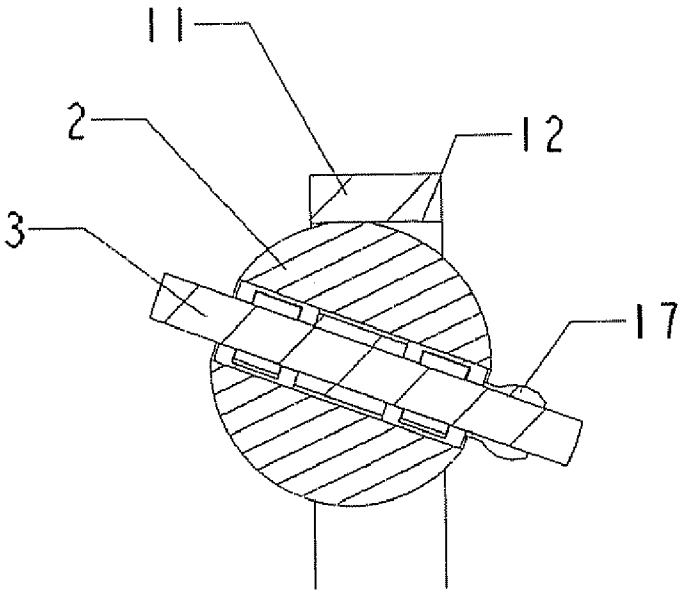


FIG. 5B

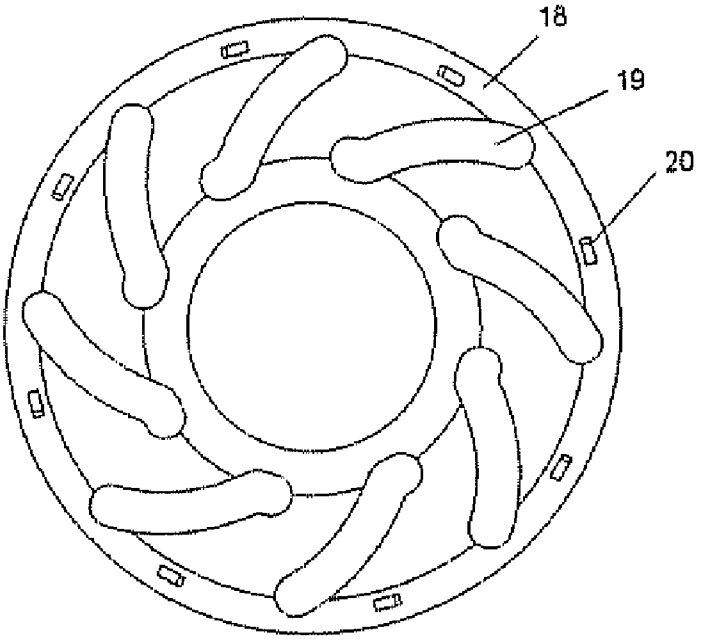


FIG. 6A

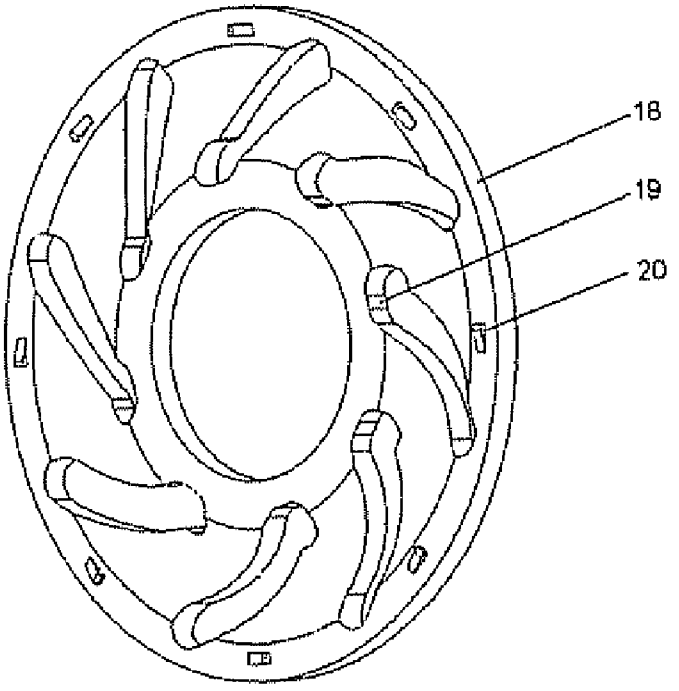


FIG. 6 B

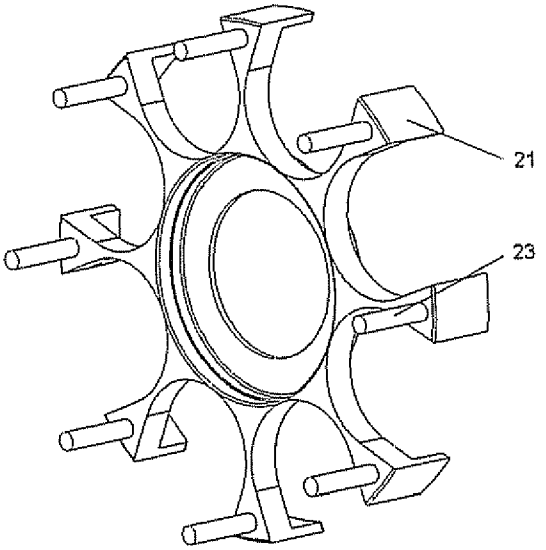


FIG. 7

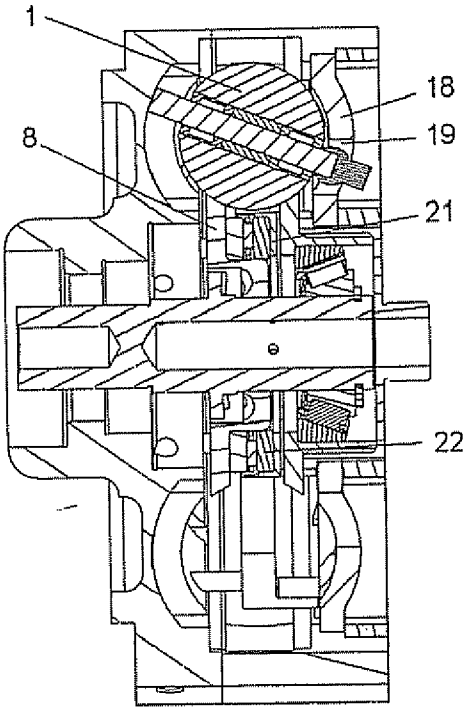


FIG. 8

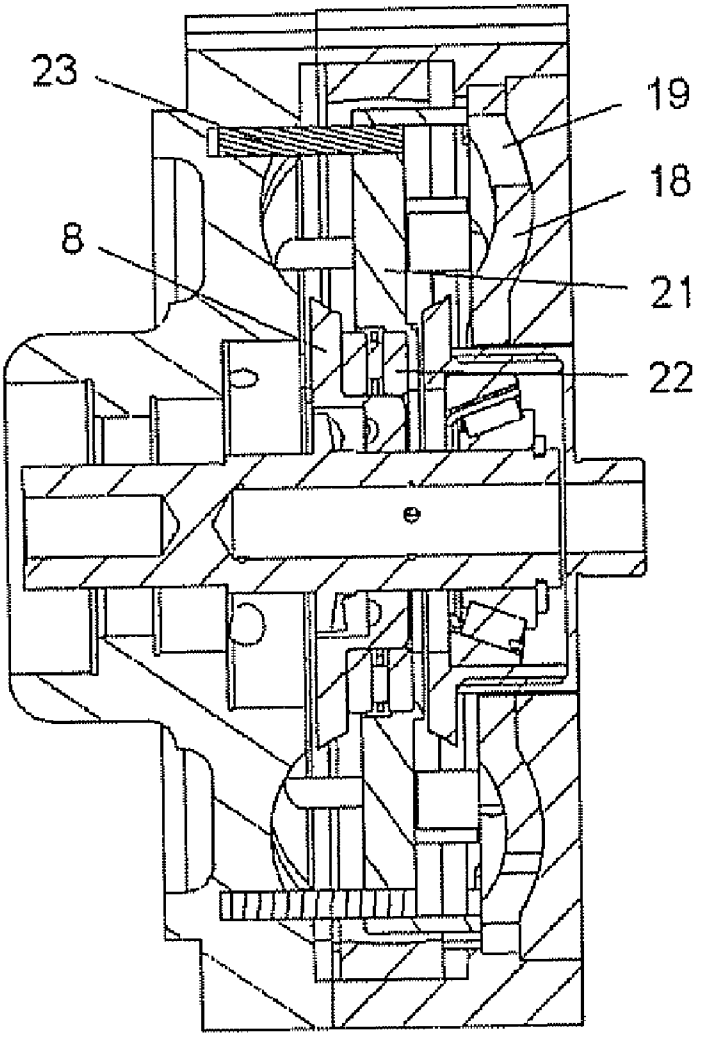


FIG. 9

CONTINUOUSLY VARIABLE GEAR TRANSMISSION

TECHNICAL FIELD

[0001] The present invention relates to a continuously variable gear transmission of the kind set forth in the preamble of claim **1**.

BACKGROUND ART

[0002] In continuously variable gear transmissions of this kind it is known to provide an axial force generator in the form of a spring to ensure the necessary contact pressure between the surfaces of the input and output discs and the traction balls. A continuously variable gear transmission of this kind is e.g. known from U.S. Pat. No. 2,469,653, in which the tension of the spring for providing the necessary contact pressure can be adjusted by means of a nut.

DISCLOSURE OF THE INVENTION

[0003] It is the object of the present invention to provide a variable gear transmission of the kind referred to above, in which the torque transfer is improved under varying loads and during fast change of transmission ratio, and having an efficient, simple and compact design compared to the prior art. This object is achieved with a continuously variable gear transmission of said kind, which according to the present invention also comprises the features set forth in the characterising part of claim **1**. With this arrangement, the forces from the pre-spanning ring, having a curvature with a radius larger than the radius of the traction balls and a pre-span, will provide the necessary normal forces in the contact points when the transmission is running with a constant ratio, in which situation the traction balls and the pre-spanning ring will have contact where the pre-spanning ring has its largest inner diameter. When the gear transmission ratio is increased by tilting the ball axes, the output shaft has to accelerate the driven unit and therefore a higher transfer torque is necessary. The inertia of the driven unit often has a size so that the acceleration torque is larger than the transferred torque when the gear is not in the transient phase.

[0004] The fast tilt of the traction ball axes will make the pre-spanning ring move axially in the same direction as the ball surface. When the pre-spanning ring moves axially, the normal force will change because of the changed inner diameter at the contact point. When the transmission ratio stops changing, the pre-spanning ring will move back to its normal position with contact point at the largest inner diameter with a speed related to the operating speed.

[0005] The exact curvature of the inner surface of the pre-spanning ring can be designed to match the requirements of the specific usage, e.g. a smaller radius will mean an ability to accelerate units with greater inertia.

[0006] The continuously variable gear transmission may further be provided with an axial force generator which will increase the normal forces on the traction balls when the torque requirements rise, and decrease the forces when the torque requirements fall.

[0007] By means of the combination of the axial force generator and the curvature of the pre-spanning ring, the transmission will automatically adjust to the prevailing load situation.

[0008] Preferably all forces for providing the required torque are internal and limited to the input shaft, from the axial force generator to the input disc, the traction balls, the pre-spanning ring, the output disc and through a thrust bearing back to the input shaft. Thus, these forces are not transferred through the housing.

[0009] The position of the traction balls is controlled by their three-point contact, and the angle of the traction ball axles can be controlled by a rotatable iris plate. The iris plate is a disc or plate with spiral grooves, and the iris plate is shaped to fit around the curvature of the traction balls, keeping a constant distance to the traction balls.

[0010] The axles of the traction balls pass through the radial grooves in the support plate and the spiral grooves in the iris plate and when the iris plate is rotated, the axles will tilt. In order to provide room for the tilting movement, the grooves in the iris plate are wider than the diameter of the axles and in order to prevent play, the axles are fitted with iris rollers having a diameter equal to the width of the grooves in the iris plate. Different systems for rotation of the iris plate can be envisaged, such as e.g. using a step motor for controlling the transmission ratio.

[0011] If the step motor or similar actuator is connected to the support plate with the radial grooves and the support plate has a minor rotational play, the actuator forces under rapid movement can be minimised. This will be explained in the following.

[0012] If the axle of each traction ball is lying in a plane through the input shaft respectively, the balls are performing a pure rolling and the ball axles are stable.

[0013] If the radial grooves in the housing and support plate are not perfectly aligned, the ball axle is tilted and the ball will behave like a turning wheel on a car. Because is it axially fixed it can only start tilting in the groove.

[0014] This reaction will continue until the ball axles hit the stops in the grooves and the reaction time and direction will be dependent upon the size of the misalignment and the turning direction of the support plate relative to the rotational direction of the input disc.

[0015] If the rotational direction of the input disc is clockwise and the support plate is provided with a small rotation clockwise, the front ends of the ball axles will move towards the rotational axis of the input shaft. If the support plate is rotated counter clockwise, the front ends of the ball axles will move away from the rotational axis of the input shaft. Thus by controlling the rotational position of the support plate it is possible to enforce and support the activation of the iris plate.

[0016] If the actuator housing is connected to the support plate and the actuator arm is connected to the iris plate, these will always move in opposite directions, and if the support plate is flexibly mounted with springs forcing it towards the ideal aligned position, the actuator forces can be kept to a minimum and at the same time providing a quick actuation.

[0017] As a simplistic alternative the supporting rotation of the support plate can be provided by means of that part of the force from the iris plate to the traction ball axles, which is not directed in the radial direction of the grooves in the support plate. This solution will only require that the turning of the iris plate for reducing the transmission ratio is chosen in accordance with the corresponding rotational direction of the input disc, and naturally that the support plate is flexibly mounted with a possibility of a small rotation.

[0018] In an alternative embodiment the continuously variable gear transmission further comprises a disengagement mechanism, which lets the driven unit freewheel relative to the driving unit, when no drive of the driven unit is needed.

Preferably the disengagement mechanism is controlled by the iris plate in such a way that with the transmission in its lowest ratio further turning of the iris plate keeps the traction ball axles in the same position and ramps on the iris plate transfers a force through a clutch plate to the input disc, which consequently is disengaged from the traction balls, thus disengaging the connection between the driving unit and the driven unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Embodiments of the invention will be described more fully below with reference to the drawing, in which

[0020] FIG. **1** shows a sectional view of a continuous variable transmission according to the invention seen in the direction A-A in FIG. **2**,

[0021] FIG. **2** shows a side view of the continuously variable transmission showing the radial grooves in the support plate,

[0022] FIG. **3** shows the iris plate with spiral grooves,

[0023] FIG. **4**A shows a sectional view of the axial force generator,

[0024] FIG. **4***b* shows an exploded view of the axial force generator,

[0025] FIG. **5**A shows a sectional view of the pre-spanning ring and a traction ball, in the constant ratio state,

[0026] FIG. **5**B shows a sectional view of the pre-spanning ring and a traction ball after a quick tilt of the traction balls axles

[0027] FIG. **6**A shows the iris plate with modified grooves and ramps for the alternative embodiment with disengagement mechanism,

[0028] FIG. **6**B shows the iris plate of FIG. **6***a* in a perspective view more clearly showing the ramps,

[0029] FIG. **7** shows the clutch plate and control pins used in the alternative embodiment

[0030] FIG. **8** shows a sectional view of the continuously gear transmission in accordance with the alternative embodiment with the disengagement mechanism cut through a traction ball,

[0031] FIG. **9** shows a sectional view corresponding to FIG. **8**, but cut between the traction balls.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] FIG. **1** shows a section through a continuously variable transmission according to an embodiment of the invention. The transmission comprises an input shaft **1** whose rotation is to be converted into rotation of an output shaft **10**, whose one end extends out of the gear, said output shaft **10** being axially aligned with the input stub shaft **1**. As shown in FIGS. **4**A and **4**B, the input shaft **1** is connected by an axial force generator to an input disc **8**. The axial force generator consists of a number of ramps **14** on the input shaft **1**, a number of ramps **15** on the input disc **8** and in between a number of balls **16**. This axial force generator provides an axial force varying with the torque of the input shaft **1**. The slope of the ramps **14**, **15** is calculated to create an axial force to result in the needed normal force on the traction balls **2** to give the required traction.

[0033] This axial force presses the traction balls **2** towards the pre-spanning ring **11**. When the input shaft **1** rotates the traction balls **2**, they will start spinning, and the contact point between traction balls **2** and pre-spanning ring **11** will move to the axial centre of the pre-spanning ring **11**, where the inner diameter is largest, as shown in FIG. **5**A.

[0034] When the traction balls **2** are tilted rapidly, the pre-spanning ring will follow axially and the contact point will move to a point with a smaller inner diameter of the pre-spanning ring **11**, as shown in FIG. **5**B, which results in a larger normal force at the contact points of the traction balls **2**.

[0035] The positions of the traction balls are defined by the three contact points with the input disc **8**, pre-spanning ring **11** and output disc **9**, and the axles are supported by the grooves in the housing **5** and the support plate **6** shown in FIG. **2**.

[0036] The iris plate **7** shown in FIG. **3** controls the angle of the traction ball axles **3**. The axles **3** of the traction balls **2** supported by the radial grooves **4** in the housing **5** and the support plate **6** passes through the grooves **13** in the iris plate **7**. When the iris plate **7** turns, the axles **3** will tilt. In order to make it possible for the axles **3** to pass through the grooves **13** at an angle, the grooves **13** in the iris plate **7** are wider than the diameter of the friction ball axles **3**. To prevent play, the friction ball axles **3** are equipped with iris rollers **17**, which have the same diameter as the grooves **13** in the iris plate.

[0037] The iris plate **18** shown in FIGS. **6**A and **6**B comprises grooves **19**, the inner part of which maintain a constant radius, in order to provide the minimum transmission ratio in connection with disengagement. The disengagement is provided by means of the ramps **20** on the iris plate **18**, said ramps **20** forcing the clutch plate **21** shown in FIG. **7** towards the thrust bearing **22**, when the iris plate **18** is turned further onwards after reaching the minimum transmission ratio. The thrust bearing **22** will thus push the input disc **8** away from its engagement with the traction balls **2** whereby the driven unit is disengaged from the driving unit. In this situation i.e. the disengaged position of the input disc **8**, the torque on the input shaft **1** will be close to zero and thus if an axial force generator is present, the axial force will be at a minimum, further supporting the disengagement of the transmission. The rotational position of the clutch plate **21** may be controlled by means of pins **23** inserted in the housing, whereby the movement of the clutch plate **21** is limited to an axial movement.

[0038] The FIGS. **8** and **9** show different cross-sectional views of the transmission with the disengagement mechanism implemented. In FIG. **8** the cross-sectional view is provided through a traction ball **1** and in FIG. **9** a cross-sectional view is provided between the traction balls **1**.

[0039] Above the invention has been described in connection with a preferred embodiment, however, many deviations may be envisaged without departing from the scope of the following claims, such as having the pre-spanning ring positioned on the inside of the traction balls **2** and the input and output discs positioned with contact on the outside of the traction balls **2**, or other possible mechanisms for tilting the traction balls **2**, etc.

1-14. (canceled)

15. An apparatus for facilitating control of the ratio of a continuously variable transmission (CVT), the apparatus comprising:

a first member having a first plurality of radial grooves;

a second member having a second plurality of radial grooves;

wherein the first and second pluralities of radial grooves are arranged angularly about an axis; and

wherein the first and second members are configured for rotation relative to one another such that during opera-

tion of the CVT the first plurality of radial grooves can be angularly misaligned relative to the second plurality of grooves.

16. The apparatus of claim **15**, wherein the first member comprises a stationary member.

17. The apparatus of claim **16**, wherein the second member comprises a support plate configured for rotation relative to the first member.

18. The apparatus of claim **15**, wherein the first member comprises a housing member.

19. The apparatus of claim **18**, wherein the second member comprises a support plate.

20. The apparatus of claim **19**, further comprising an actuator housing and an actuator arm, the actuator housing coupled to the support plate, and the actuator arm coupled to a mechanism for tilting a plurality of traction balls of a CVT.

21. A method for facilitating control of the ratio of a continuously variable transmission (CVT), the method comprising:

providing a plurality of traction balls;

providing each traction ball with a ball axle about which the traction ball rotates;

providing a first plurality of grooves for engaging a first end of the ball axles;

providing a second plurality of grooves for engaging a second end of the ball axles; and

arranging the first and second plurality of grooves relative to one another such that during operation of the CVT the first plurality of grooves can be misaligned relative to the second plurality of grooves.

22. The method of claim **21**, wherein the first and second plurality of grooves comprise radial grooves.

23. The method of claim **21**, wherein first plurality of grooves is part of a housing.

24. The method of claim **23**, wherein the second pluraliy of grooves is part of a support plate.

25. The method of claim **24**, further comprising providing an actuator housing and an actuator arm, the actuator housing being coupled to the support plate, and the actuator arm being coupled to a mechanism for tilting the plurality of traction balls.

26. A method of controlling the ratio of a continuously variable transmission, the method comprising:

providing a plurality of traction balls;

providing a first plurality of radial grooves for engaging a first end of each of the ball axles;

providing a second plurality of radial grooves for engaging a second end of each of the ball axles; and

providing a second plurality of radial grooves for engaging a second end of the ball axles; and

rotating the first and second plurality of radial grooves relative to one another.

27. The method of claim **26**, further comprising providing an input disc in contact with the plurality of balls, and wherein a clockwise rotation of the input disc and a clockwise rotation of the second plurality of grooves results in the ball axles being tilted in a first direction in the radial grooves.

28. The method of claim **27**, wherein a counterclockwise rotation of the second plurality of grooves results in the ball axles being tilted in a second direction in the radial grooves.

29. The method of claim **26**, wherein providing a second plurality of radial grooves comprises providing a support plate comprising a plurality of radial grooves.

30.-**35**. (canceled)

36. A continuously variable transmission (CVT) comprising:

a plurality of traction balls angularly arrayed about a shaft, each traction ball provided with a ball axle about which the ball rotates;

an input disc in contact with the traction balls;

an output disc in contact with the traction balls;

a prespanning ring in contact with the balls;

wherein the input and output discs contact the balls at a position that is radially inward relative to the position where the prespanning ring contacts the balls; and

wherein the prespanning ring is configured to translate axially when the ball axles are tilted.

37. A continuously variable transmission (CVT) comprising:

a shaft;

a plurality of traction balls arrayed angularly about a longitudinal axis of the shaft;

a plurality of tiltable ball axles, each ball axle corresponding to a traction ball;

a first plurality of radial grooves engaging a first end of the balls axles;

a second plurality of radial grooves engaging a second end of the ball axles; and

wherein the first plurality of radial grooves is configured for rotation relative to the second plurality of radial grooves such that rotation of the first plurality of radial grooves causes the ball axles to tilt in the first and second pluralities of radial grooves.

38. The CVT of claim **37**, wherein the first plurality of grooves are formed in a support plate.

39. The CVT of claim **38**, wherein the second plurality of grooves is stationary and the support plate is configured to have minor rotational play about its ideal aligned position.

40. The CVT of claim **37**, further comprising an input disc, an output disc, and a prespanning ring, wherein the input disc, output disc, and prespanning ring each contacts the plurality of traction balls.

* * * * *