

Trailer and Method for Controlling the Distance Between a Trailer and a Connecting Rod

The present invention relates to a trailer with a wheel drive and to a method for controlling a trailer of this kind.

Driven trailers according to the prior art use force-measuring sensors, in particular strain gages, which measure forces arising between the trailer and the towing vehicle, for controlling the trailer drive. These force-measuring sensors are known to be susceptible to external influences, in particular environmental influences such as temperature and humidity fluctuations. In addition, the connection between the trailer and towing vehicle according to the prior art is always rigid and thus susceptible to axial as well as lateral forces between the trailer and towing vehicle. In particular, strong vibrations and even resonant oscillations can occur in the trailer-towing vehicle system. This causes the force-measuring sensor to generate a large amount of measurement data, which in turn leads to a high evaluation workload for the control unit. It is also difficult to distinguish the measurement data that are essential for controlling the trailer from the background noise generated by vibrations and other disturbance variables. This compromises, inter alia, the riding comfort and increases the energy consumption.

A motor-driven trailer for a bicycle is known from US 2012/0037435 A1. The trailer described there is connected to the bicycle via a tow bar, wherein the tow bar has a force meter and the trailer has a motor. Depending on the speed difference between the bicycle and the trailer, the force meter measures a compressive force when the trailer is faster than the bicycle or a tensile force when the trailer lags behind the bicycle. The motor accelerates the trailer according to the forces measured by the force-measuring sensor.

US 8,365,849 B2 describes a system for towing a trailer. The trailer comprises an electric motor, brakes, a tow bar, and a force-measuring sensor arranged on the tow bar. The trailer is accelerated via the motor or braked via the brakes depending on the mechanical forces measured at the force meter.

DE 10 2010 051 838 A1 describes a trailer for a bicycle, wherein the trailer comprises an electric machine which can act both as a brake and as a motor in order to prevent the trailer from having a noticeable reactive effect on the bicycle when the bike is pushed or braked. To achieve this, different sensors are described. For example, a pedal pressure sensor, a braking force sensor provided in the brake lever, and a force-measuring sensor provided in the connection between the bicycle and the trailer are proposed. The signals from these sensors are transmitted to an electronic logic circuit, which in turn actuates the electric machine and/or brakes. The force-measuring sensor can be used to ascertain whether the bicycle is exerting a tensile force or a compressive force on the trailer, wherein the motor or else the brakes are actuated depending on the measured signals in order to reposition the trailer relative to the bicycle. As an alternative to the force measurement, preloaded measuring systems are proposed, wherein either a pressure sensor records a pressure change in a cylinder or a position sensor measures the position of a spring-mounted disc. Although preloaded measuring systems of this kind have a less rigid coupling between the trailer and the bicycle, there still remain interfering, in particular pulsating, feedback effects.

DE 10 2006 009 862 A1 describes a bicycle push trailer for driving and braking a bicycle, wherein a battery is mounted as an inertial mass in a frame of the trailer, such that the battery swings forward during a braking movement and swings backward during an acceleration movement. The battery is connected in an articulated manner via a control lever to an actual-position-value transmitter and to a Bowden cable. During a braking process, an electric motor is recuperatively operated via the actual-position-value transmitter, while at the same time a mechanical brake is activated via the Bowden cable.

US 2013/0311058 A1 discloses a method for controlling a trailer driven by means of an electric motor.

EP 3 416 860 A1 relates to a method for controlling a driven trailer and to a motor-driven trailer. The method comprises, inter alia, a step in which a distance between the trailer and towing vehicle is defined as a neutral position. The deviation of the distance between the trailer and towing vehicle from the neutral position is measured

and output as a distance value. If the distance between the trailer and towing vehicle is reduced by at least one first distance value relative to the neutral position, the trailer is electrically braked. If the distance between the trailer and towing vehicle is reduced by at least one second distance value relative to the neutral position, wherein the second distance value is greater than the first distance value, the trailer is mechanically braked independently of the electrically actuated brakes. If the distance between the trailer and towing vehicle is increased by a third distance value relative to the neutral position, the trailer is accelerated by means of an electric motor.

Proceeding from this, the object of the invention is to allow for the most sensitive control possible of a driven trailer.

The object is achieved by a trailer according to claim 1 and by a method for controlling the distance according to claim 10. Advantageous embodiments are addressed in the dependent claims and the description.

The trailer according to the invention with at least one driven wheel comprises

- an energy source which is designed to provide a wheel drive with energy,
- a braking apparatus for decelerating the at least one wheel,
- a connecting rod which is designed to be connected to a towing apparatus and which is movably mounted to the trailer,
- a displacement sensor which is designed to measure the position of the connecting rod relative to the trailer,
- a speed-measuring apparatus which is designed to determine the travel speed based on a measurement of the speed of the trailer and/or connecting rod,
- and
- an electronic controller,

and is characterized in that

- the controller is designed

- to shift the position of a neutral point relative to the trailer proceeding from a zero point depending on the determined travel speed,
- to calculate a control deviation with the distance between the position of the neutral point and the measured position of the connecting rod, and
- to actuate the wheel drive and/or braking apparatus with the control deviation.

The trailer has one or more wheels. It may thus stand upright on its own or only stand upright in combination with a towing vehicle or be held upright by an operator. At least one of the wheels is driven by a drive. The drive is preferably an electric motor. The electric motor can either be designed as a wheel hub motor or be mounted on the trailer and drive the driven wheel via a drive shaft. Furthermore, the trailer has an energy source with which the drive is supplied with energy. In the case of an electric motor, this may be a battery. A fuel cell or photovoltaics may also be used. If an internal combustion engine is used, a corresponding fuel tank with a fuel supply is used. In addition to the drive, the trailer also has a braking apparatus which acts on the at least one wheel in order to decelerate same and thus the trailer. The drive and the braking apparatus can, if the trailer has multiple wheels, be designed such that they can act on various wheels independently of one another. The braking apparatus can have a mechanical brake, for example a disc brake or a block brake, by means of which the at least one wheel or a shaft fastened to said wheel is braked. The braking apparatus may also comprise an apparatus that is designed to actuate the drive such that same generates a braking effect. In the case of an electric motor, this may be regenerative operation of the electric motor, which results in electric braking. In the case of an internal combustion engine, this may be suspending the supply of fuel, such that it outputs no drive power in order to utilize the internal friction of the internal combustion engine as an engine brake, which results in braking.

The trailer comprises a connecting rod which is designed to be connected to a towing apparatus. A drawbar is used for connection to a towing vehicle and is attached to the vehicle by means of the towing apparatus. A towing vehicle may, in particular, be a

bicycle. By means of the towing apparatus, the trailer may be towed by a person or an animal.

The connecting rod is fastened to the trailer by means of a bearing, such that it can move relative to the rest of the trailer. Suitable bearings, such as linear guides or ball bearings, can be used for the mounting. Different degrees of freedom can be provided for the connecting rod depending on the characteristics of the bearing. The bearing absorbs forces only in the directions in which it provides no degrees of freedom for the connecting rod.

The trailer has a displacement sensor. The displacement sensor is designed to measure the position of the connecting rod relative to the trailer. For this purpose, the displacement sensor determines a point fixedly connected to the connecting rod in a coordinate system that is fixed with respect to the displacement sensor. The orientation of the coordinate system of the displacement sensor relative to the bearing with which the connecting rod is mounted is fixed. If, for example, the mounting is rotatable about a vertical axis of the trailer, the position of the connecting rod relative to the trailer is defined as the position of the connecting rod relative to the part of the trailer that can rotate with the mounting. With a corresponding rotation of the bearing, the measured position of the connecting rod thus does not change relative to the corresponding part of the trailer. If the connecting rod is rigidly connected to the towing vehicle or to the towing apparatus, the position of the towing vehicle or of the towing apparatus relative to the trailer is calculated by adding a corresponding distance vector.

The trailer has a speed-measuring apparatus. The speed-measuring apparatus is designed to determine the travel speed. For this purpose, it uses measurements of the speed of the trailer and/or connecting rod relative to a world coordinate system. The measurement of the speed of the trailer and/or connecting rod is thus absolute or rather relative to the stationary world and not relative to a movable coordinate system, for example the above-mentioned coordinate system of the displacement sensor. According to one embodiment, the speed-measuring apparatus can be designed to carry out these measurements.

The trailer has an electronic controller which is designed to actuate the drive and the braking apparatus. In response, the drive and/or the braking apparatus change the output drive and/or braking force, such that the trailer is accelerated or decelerated. The controller can define the actuation by means of a control specification. The control specification can be, for example, an electronic circuit that is integrated in the controller or a computer program that is stored on the controller. The controller may be a microcontroller. The controller takes the control deviation into account as an input signal. The control specification may in each case have a component which calculates the control signal proportionally to the control deviation, proportionally to the change in the control deviation, and proportionally to the integral of the control deviation. By configuring the control specification in a manner tailored to the properties of the trailer as well as of the drive and braking apparatus, the drive and braking apparatus can be actuated in an optimal manner. Ideally, this can mean one or various control targets being met. It is preferable for the control deviation to be as constant and low as possible. Moreover, it is preferable for a control deviation to be corrected quickly after same emerges. A challenge with this is that disturbance variables can affect the system. This includes, in particular, the towing vehicle or else the towing apparatus changing its speed. Surface unevenness or other environmental conditions, such as variable wind speeds, constitute disturbance variables. As soon as a disturbance variable of this kind affects the control deviation, the controller attempts to minimize the control deviation quickly by means of a corresponding actuation of the wheel drive and of the braking apparatus. A collision of the connecting rod with other components of the trailer must be avoided at all costs.

The controller calculates the control deviation by calculating a difference between a neutral point and the position of the connecting rod. As with the position of the connecting rod, the neutral point is defined relative to the trailer, in particular within the coordinate system of the displacement sensor. If there is no control deviation, the trailer is neither accelerated nor decelerated. The computing apparatus uses the travel speed to determine the neutral point. The relationship between the neutral point and these measurement variables can be stored on the controller, for example in the form of a saved computer program or an algorithm or a lookup table. The controller is designed such that the neutral point is defined relative to the trailer, i.e. within the

coordinate system of the displacement sensor, depending on the travel speed. For this purpose, the controller shifts the neutral point proceeding from a zero point that is stationary relative to the trailer or rather to the displacement sensor coordinate system.

Shifting the neutral point depending on a measured speed is advantageous in that sensitive control in which the operator or the towing vehicle are not influenced by the trailer can be achieved in a simplified manner.

According to the above description, the actuation of the wheel drive and braking apparatus, which accelerates or decelerates the trailer, depends on the controller and the control deviation. It is usually advantageous if the controller does not provide an actuation signal that results in a strong acceleration or deceleration at very small control deviations. Measurement uncertainties as well as inaccuracies in the mechanics or electrics mean that optimal control is not possible. Thus, the controller is usually designed such that a sufficiently large control deviation must be present in order to trigger an actuation signal that accordingly prompts a strong acceleration or deceleration. The control strategy should therefore not react too sensitively to the control deviation. A disadvantage of such a control strategy is that, even during normal operation, there must be large distances between the connecting rod and the trailer in order to create a sufficiently large control deviation. If an additional disturbance variable unexpectedly occurs, there is a further shift between the connecting rod and the trailer. This shift can be so large that a collision occurs between the connecting rod and other components of the trailer.

A solution to this problem would be to increase the freedom of movement of the connecting rod between the respective end stops. However, the installation space required for this is disadvantageous for the design of the trailer. The invention solves this dilemma. According to the invention, the controller is designed to change the neutral point used for calculating the control deviation depending on the travel speed. The neutral point changed in this manner can be shifted nearer to the center of gravity of the trailer or further away therefrom at higher speeds, depending on the characteristics of the controller. By changing the neutral point in this manner, the freedom of movement available to the connecting rod can be lengthened virtually. In this way, a larger

control deviation that allows for sensitive control can be tolerated without there being the risk of the connecting rod colliding with the rest of the trailer. This avoids having to provide more installation space.

According to one embodiment of the invention, the trailer is characterized in that the displacement sensor is designed as an inductive displacement sensor, a capacitive displacement sensor, or a resistance-change displacement sensor.

The above-mentioned sensors typically consist of a stationary component and a movable component. A change in the relative position between said components produces a change in an electromagnetic property of the stationary component, which is measured and output as a distance measurement signal by way of calculation with a proportionality factor or a corresponding function. Preferably, a sensor target is fastened on the connecting rod and a signal receiver is fastened on the trailer, which signal receiver measures a change in the distance between it and the sensor target by changing an inductance.

The above-mentioned sensors stand out due to the fact that they are cheap, robust, and accurate. Furthermore, these are electronic components which can be connected to the remaining electronics particularly easily.

According to a further embodiment, optical sensors or radar-assisted sensors are used.

According to one embodiment, the trailer is characterized in that the connecting rod is mounted on the trailer so as to be shiftable along its longitudinal axis toward a side nearer the trailer and toward a side further away from the trailer.

The mounting according to this embodiment only gives the connecting rod one degree of freedom for the movement relative to the trailer. This thus ensures that the connecting rod can only move along its longitudinal axis toward a side nearer the trailer and toward a side further away from the trailer. The side further away from the trailer is closer to the center of gravity of the trailer than the side further away from the trailer. On account of the degree of freedom defined by the mounting, a position of the

connecting rod relative to the trailer can be expressed as a scalar distance between the connecting rod and a fixed point on the trailer or rather within the displacement sensor coordinate system. The mounting may, in particular, be a linear guide.

The advantage of using a mounting that affords the connecting rod only one degree of freedom along its longitudinal axis is that control can be improved. Specifically, a mounting of this kind restricts the degrees of freedom such that it is easier to model the physical processes when the distance changes and for the controller to take same into account.

According to one embodiment, the trailer has a further mounting which allows for a rotation of the displacement sensor and components of the trailer rigidly connected thereto relative to the rest of the trailer. The further mounting may be, in particular, a mounting that allows for a rotation about the vertical axis. All relative details relating to the trailer relate, in such a case, to the components of the trailer that are rigidly connected to the displacement sensor and the coordinate system thereof.

According to one embodiment, the trailer is characterized in that the calculation specification is designed to shift the neutral point proceeding from the zero point, which is located on the longitudinal axis, along the longitudinal axis toward the side further away from the trailer by a correction distance that is positively proportional to the determined travel speed minus a zero speed.

According to this embodiment, the controller uses a linear relationship to calculate the position of the neutral point. According to the relationship, the neutral point is defined by the correction distance and the zero point lying on the longitudinal axis. The neutral point corresponds to the zero point after it has been shifted by the controller virtually by the correction distance along the longitudinal axis away from the center of gravity of the trailer, i.e. toward the side further away from the trailer. The correction distance is calculated using the travel speed. For this purpose, the zero speed is subtracted from the travel speed and this difference is multiplied by a proportionality factor.

The position of the neutral point p is given by the zero position p_0 , the correction distance Δp , the proportionality constant c , the travel speed v , and the zero speed v_0 according to the following relationship:

$$p = \Delta p + p_0 = c (v - v_0) + p_0.$$

This relationship means that, if the travel speed corresponds to the zero speed, the neutral point corresponds to the zero point, and therefore the neutral point is not shifted. It is only when the travel speed increases beyond the zero speed that the neutral point is shifted relative to the zero point toward the side further away from the trailer. At lower speeds, the neutral point is in turn shifted relative to the zero point toward the side nearer the trailer. At higher speeds, the neutral point accordingly migrates toward the towing apparatus and at lower speeds away therefrom.

The advantage of the described design of the controller is that sensitive control is facilitated. At high speeds, there may be a large distance between the connecting rod and the side nearer the trailer, but only a small control deviation is calculated. The connecting rod is thus located relatively far away from the side nearer the trailer. In the event of a braking procedure by the towing vehicle, the connecting rod can move a long way before it reaches the end of the mounting or rather before a collision occurs with other components of the trailer. Thus, a correspondingly large control deviation may arise without there being a collision.

Accordingly, conversely, at low speeds, a small control deviation is calculated at a small distance between the side nearer the trailer and the connecting rod. As soon as the towing vehicle or the towing apparatus is accelerated, wherein, at low speeds, the acceleration is typically stronger than at high speeds, a large control deviation can arise before the connecting rod collides.

The speed-variable shifting of the neutral point allows for virtual lengthening of the free space available to the connecting rod without there being a collision. This utilizes the fact that the connecting rod must above all be at a large distance from the side nearer the trailer at high speeds and must be at a large distance from the side further

away from the trailer at low speeds in order to be able to prevent corresponding collisions. On account of the virtual lengthening, larger control deviations can consequently be tolerated.

It is advantageous to design the controller such that it works with larger control deviations. The electronic and mechanical components used cause inaccuracies in the controller; for example, the position measurement signal may be subject to noise, or a corresponding analog/digital converter creates a time delay. These inaccuracies mean that, in the case of small control deviations, a relatively large proportion of the control deviation can be traced back to the above-mentioned inaccuracies. Using such an error-prone control deviation for actuating the drive and braking apparatus could result in excessively strong or weak acceleration or else deceleration. If, as provided by the invention, a large control deviation is used, the corresponding inaccuracies are less significant compared with the remaining control deviations. They therefore do not result in distortion of the control signal either.

According to one embodiment, the trailer is characterized in that the controller is designed to calculate the correction distance in a negatively proportional manner to the determined travel speed minus the zero speed if the determined speed is less than a start-up speed that is lower than the zero speed.

According to this embodiment, there is a start-up speed that is lower than the zero speed. If the travel speed is below a limit speed, the previously described linear mathematical function is no longer used with a positive proportionality factor to calculate the correction distance. Instead, a steadily decreasing function is used. The corresponding function is configured such that it constantly aligns itself with the function at higher speeds. Thus, according to this embodiment, at speeds below the start-up speed, i.e. at very low speeds, correction distances are calculated that are greater than the correction distance calculated at the start-up speed.

This causes the neutral point to be shifted somewhat further toward the side further away from the trailer. Thus, in a state without a control deviation, there is a larger distance between the neutral point and the side nearer the trailer. Wobbling or other

instability during start-up then do not result directly in a collision between the connecting rod and the other components of the trailer.

According to one embodiment, the trailer is characterized in that the controller is designed to only actuate the wheel drive and/or the braking apparatus if the control deviation is greater than a tolerance deviation.

The advantage of a tolerance deviation is that small control deviations do not immediately to actuation of the wheel drive and/or braking apparatus. In particular, small control deviations may arise due to non-uniform tensile loading of the connecting rod. Non-uniform tensile loading is typical when the towing vehicle is a bicycle that is driven by the operator pedaling. At high speeds, in particular, strong accelerations or decelerations would be required in order to prevent even small control deviations at any given time. This would put strain on the wheel drive and braking apparatus. Providing a tolerance deviation thus results in reduced loading of the wheel drive and braking apparatus as well as of the trailer as a whole.

According to one embodiment, the trailer is characterized in that the controller is designed to calculate the tolerance deviation in a positively proportional manner to the determined travel speed.

It is advantageous to select the tolerance deviation to be larger at high speeds. At such speeds, in particular, permanent actuation of the wheel drive and braking apparatus would result in accelerated wear of said components.

According to one embodiment, the trailer is characterized in that a mechanical brake actuation apparatus is present which is designed to mechanically actuate the braking apparatus if the distance between the trailer and connecting rod falls below a limit distance.

According to this embodiment, the trailer has a mechanical brake actuation apparatus for the braking apparatus. Said mechanical brake actuation apparatus serves as a redundancy to the electrical actuation of the braking apparatus by the controller. The

brake actuation apparatus is designed such that it is mechanically triggered as soon as the connecting rod comes closer than a limit distance from the trailer. This may, in particular, be a very short distance between a part of the connecting rod and, for example, an end stop. However, a different device of the connecting rod, for example a protruding catch, and a corresponding stop on the trailer may be provided in order to form the brake actuation apparatus.

The advantage of a mechanical brake actuation apparatus is that effective braking is provided even in the event of a power failure or excessively slow control of the trailer. This prevents a collision between the trailer and the towing apparatus and corresponding damage can be prevented. The mechanical brake actuation apparatus thus increases the safety of the trailer during operation.

According to one embodiment, the trailer is characterized in that the mechanical brake actuation apparatus

- a) comprises a lever that is designed to be flipped by the connecting rod as soon as the distance falls below the limit distance, and
- b) comprises a cable that is connected to the braking apparatus and to the lever and is designed to be tensioned by the lever being flipped.

According to this embodiment, the mechanical brake actuation apparatus is designed as a cable. The cable is actuated by a lever which is flipped by the connecting rod when the distance falls below the limit distance. An embodiment of this kind uses tried-and-tested components and is therefore particularly reliable.

The object is also achieved by a method according to claim 10 for controlling the distance between a trailer with at least one wheel, a wheel drive as well as a braking apparatus, and a connecting rod which is designed to be connected to a towing apparatus and which is movably mounted to the trailer, which method comprises the steps of

- measuring a position of the connecting rod relative to the trailer,

- measuring a speed of the trailer and/or a speed of the connecting rod,
- determining a travel speed based on the speed of the trailer and/or the speed of the connecting rod,
- controlling the actuation of the wheel drive and/or braking apparatus using a control deviation,

and is characterized in that

- the position of a neutral point is shifted relative to the trailer proceeding from a zero point with the travel speed,
- the control deviation is calculated with the distance between the position of the neutral point and the position of the connecting rod.

The method is, in particular, suitable for being carried out with the trailer according to the invention. The above-mentioned advantages of the trailer according to the invention and of embodiments thereof also apply analogously to the method and to embodiments thereof.

According to one embodiment, the method is characterized in that

- the connecting rod is shifted along its longitudinal axis toward a side nearer the trailer or a side further away from the trailer,
- the neutral point is shifted proceeding from the zero point, which is located on the longitudinal axis, along the longitudinal axis toward the side further away from the trailer by a correction distance that is positively proportional to the travel speed minus a zero speed.

According to one embodiment, the method is characterized in that the correction distance is calculated in a negatively proportional manner to the travel speed if the determined travel speed is less than a start-up speed that is lower than the zero speed.

According to one embodiment, the method is characterized in that the wheel drive and/or the braking apparatus are only actuated if the control deviation is greater than a tolerance deviation.

According to one embodiment, the method is characterized in that the tolerance deviation is calculated in a positively proportional manner to the travel speed.

According to one embodiment, the trailer is characterized in that the braking apparatus is mechanically actuated if the distance between the trailer and connecting rod falls below a limit distance.

In the following, the invention will be explained further based on an exemplary embodiment. In the appended drawings, the figures show:

Fig. 1: a trailer according to the invention and a bicycle;

Fig. 2: a function diagram of the trailer;

Fig. 3: a schematic representation of a distance-measuring apparatus;

Fig. 4: a schematic representation of an oscillating distance between the trailer and the towing vehicle;

Fig. 5: a schematic representation of the correction distance as a function of the travel speed.

Fig. 1 shows a trailer according to the invention 1 and a bicycle 2. The trailer 1 and the bicycle 2 are connected by means of a coupling rod 3. The trailer has a wheel drive that is not specifically shown in this view. The wheel drive drives the trailer 1 such that same follows the bicycle 2 without the bicycle rider having to exert any muscle power.

Fig. 2 shows a function diagram of the trailer 1. In the function diagram, the acceleration and deceleration apparatus 4 is drawn in, said apparatus comprising a wheel drive and a braking apparatus. It is supplied with energy required for driving by an energy source 5. In the process, the drive and the braking apparatus are actuated by the controller 6. The actuation takes place in such a way that the bicycle rider, or a different towing vehicle, if possible does not notice that the trailer 1 is following on behind the bicycle. In order to ensure appropriate control, the distance-measuring apparatus 7 measures the distance between the bicycle 2 and the trailer 1. The distance is transmitted to the controller 6.

Fig. 3 shows a schematic representation of a distance-measuring apparatus 7. The distance-measuring apparatus 7 has a housing 8 which is rigidly connected to the rest of

the trailer 1. A connecting rod 9 protrudes into the housing. The connecting rod 9 is connected to the slider 10, which is movably fastened on the linear guide 11. The linear guide 11 defines the degree of freedom that can be covered by the connecting rod 9 during a movement relative to the housing 8. The freedom of movement of the connecting rod 9 is limited by the wall of the housing on the right-hand side, which the connecting rod touches via the rubber end stop 12 as soon as the connecting rod 9 has moved as far as possible to the right. On the left-hand side, the freedom of movement is limited by the rubber end stop 13. The right-hand side corresponds to a side further away from the trailer and nearer the bicycle. The left-hand side consequently corresponds to a side nearer the trailer. The corresponding stops in the form of the rubber end stops 12, 13 define an end of the path further away from the trailer and an end of the path nearer the trailer, which path can be covered by the connecting rod 9.

A sensor target 14 is fastened on the connecting rod 9. The displacement transducer 15 is able to ascertain the position of the sensor target 14 relative to it. The displacement transducer 15 and the coordinate system thereof are rigidly connected to the housing 8 and thus to the trailer 1. The measurement of the position of the sensor target 14 relative to the displacement transducer 15 thus corresponds to a measurement of the connecting rod 8 relative to the trailer 1. The displacement transducer 15 is an inductive displacement transducer. The sensor target 14 and the displacement transducer 15 form a displacement sensor.

The controller 6 is designed to subtract a position of a neutral point from the measured position of the connecting rod and thus calculate the control deviation. The controller 6 controls the wheel drive and braking apparatus according to the control deviation, such that the trailer 1 is accelerated or braked. On account of the linear guide 11, the connecting rod 9 can only move along a defined path relative to the housing 8 and trailer 1, namely along the longitudinal axis of the connecting rod 9. The neutral point is also located on the longitudinal axis. The control deviation can therefore also be expressed by a distance along the longitudinal axis. The control deviation is positive or negative depending on whether the connecting rod is located closer to the side further away from the trailer or closer to the side nearer the trailer relative to the neutral point.

As soon as the connecting rod 9 touches the rubber end stop 13 that is nearer the trailer and continues to move toward the wall of the housing 8 nearer the trailer, the lever 16 is flipped. In the process, it rotates about the bearing point 17. The cable 18 is tensioned by the lever 16 being flipped. The cable 18 is connected to the braking apparatus of the trailer 1. The lever 16 and the cable 18 are a mechanical brake actuation apparatus which actuates the braking apparatus as soon as the distance between the trailer 1 and the bicycle 2 as well as the connecting rod 8 connected to the bicycle 2 falls below a limit distance.

Fig. 4 shows a schematic representation of an oscillating distance 19 between the trailer 1 and towing vehicle 2 which arises due to the pedaling of the bicycle rider. Compensating for this distance 19 by accelerating or decelerating the trailer 1 accordingly would result in significant loading of the drive train.

Fig. 5 shows a schematic representation of the correction distance as a function of the travel speed, wherein the correction distance is shown on the horizontal axis and denoted by "Position" and the travel speed is shown on the vertical axis and denoted by "Speed". The travel speed corresponds in this exemplary embodiment to the trailer speed, but it may also correspond to the bicycle speed or a calculation of these two speeds.

The correction distance is used for shifting the neutral point along the longitudinal axis. Consequently, there is no control deviation at different travel speeds in each case at a different position of the connecting rod 9 relative to the displacement transducer 15 or else to the housing 8 or else to the trailer 1.

The representation shows positions of the connecting rod 9 at which no control deviation is present for four different travel speeds. The position 21 is assigned to a zero speed 20. The position 22 is assigned to a higher travel speed. The position 24 is assigned to a start-up speed 23. The position 25 is assigned to a travel speed below the start-up speed.

The representations for the positions 21, 22, and 24 show that, when the travel speed increases, the connecting rod 9 must move further toward the right-hand side further away from the trailer such that no control deviation is present. This is due to the shown course of the correction distance, which increases with increasing travel speed and is added to the zero position in order to calculate the neutral point. There is no correction distance at the zero speed 20. The zero point corresponds to the neutral point. In the state shown, the connecting rod 9 is located in the center between the side nearer the trailer and the side further away from the trailer without a control deviation. The correction distance is positive above the zero speed 20, and therefore the neutral point is shifted toward the side further away from the trailer. The neutral point is shifted toward the side nearer the trailer below the zero speed 20. Accordingly, the connecting rod 9 must be shifted toward the side nearer the trailer or the side further away from the trailer such that there is no control deviation. The correction distance increases again below the start-up speed 23. Accordingly, the connecting rod must again move somewhat further toward the side further away from the trailer such that there is no control deviation.

The speed dependency of the correction distance means that the neutral point and thus also the connecting rod 9 are closer to the side further away from the trailer at high speeds. As a result, a large control deviation may arise when the bicycle 2 is braked, before the connecting rod 9 touches the end nearer the trailer in the form of the rubber end stop 13. Conversely, the speed dependency of the correction distance also means that the neutral point and thus the connecting rod 9 are closer to the end nearer the trailer at low speeds. As a result, a large control deviation may arise when the bicycle 2 is accelerated, before the connecting rod 9 touches the end further away from the trailer in the form of the rubber end stop 12.

Large control deviations are less affected by noise caused by mechanical and electronic inaccuracies of the components used. A large control deviation thus allows for sensitive control. At very low speeds, the correction distance is selected such that the neutral point is somewhat further away from the side nearer the trailer in order to compensate for jerking or wobbling during start-up.

Fig. 5 further shows that a tolerance deviation 26 is present. The control deviation must be so large that the position of the connecting rod 9 lies outside the relevant tolerance deviation, such that the controller 6 actuates the acceleration and deceleration apparatus 4. The tolerance deviation 26 increases with increasing travel speed. The tolerance deviation prevents the acceleration and deceleration apparatus from being actuated at relatively small control deviations. This spares the acceleration and deceleration apparatus and prevents wear.

Reference Signs

- 1 Trailer
- 2 Bicycle
- 3 Coupling rod
- 4 Acceleration and deceleration apparatus
- 5 Energy source
- 6 Controller
- 7 Distance-measuring apparatus
- 8 Housing
- 9 Connecting rod
- 10 Slider
- 11 Linear guide
- 12 Rubber end stop further away from trailer
- 13 End stop nearer trailer
- 14 Sensor target
- 15 Displacement transducer
- 16 Lever
- 17 Bearing point
- 18 Cable
- 19 Oscillating distance
- 20 Zero speed
- 21 Position at zero speed
- 22 Position at higher speed
- 23 Start-up speed
- 24 Position at start-up speed
- 25 Position at speed below start-up speed
- 26 Tolerance deviation

Claims

- 1) A trailer (1) with at least one driven wheel, comprising
 - an energy source (5) which is designed to provide a wheel drive with energy,
 - a braking apparatus for decelerating the at least one wheel,
 - a connecting rod (9) which is designed to be connected to a towing apparatus and which is movably mounted to the trailer,
 - a displacement sensor which is designed to measure the position of the connecting rod (9) relative to the trailer (1),
 - a speed-measuring apparatus which is designed to determine the travel speed based on a measurement of the speed of the trailer and/or connecting rod, and
 - an electronic controller (6),
characterized in that
 - the controller (6) is designed
 - to shift the position of a neutral point relative to the trailer (1) proceeding from a zero point depending on the determined travel speed,
 - to calculate a control deviation with the distance between the position of the neutral point and the measured position of the connecting rod (9), and
 - to actuate the wheel drive and/or braking apparatus with the control deviation.
- 2) The trailer (1) according to the preceding claim, characterized in that the displacement sensor is designed as an inductive displacement sensor, a capacitive displacement sensor, or a resistance-change displacement sensor.

- 3) The trailer (1) according to one of the preceding claims, characterized in that the connecting rod (9) is mounted on the trailer (1) so as to be shiftable along its longitudinal axis toward a side nearer the trailer and toward a side further away from the trailer.
- 4) The trailer (1) according to the preceding claim, characterized in that the controller (6) is designed to shift the neutral point proceeding from the zero point, which is located on the longitudinal axis, along the longitudinal axis toward the side further away from the trailer by a correction distance that is positively proportional to the determined travel speed minus a zero speed.
- 5) The trailer (1) according to the preceding claim, characterized in that the controller (6) is designed to calculate the correction distance in a negatively proportional manner to the determined travel speed minus the zero speed if the determined speed is less than a start-up speed that is lower than the zero speed.
- 6) The trailer (1) according to one of the preceding claims, characterized in that the controller (6) is designed to only actuate the wheel drive and/or the braking apparatus if the control deviation is greater than a tolerance deviation.
- 7) The trailer (1) according to the preceding claim, characterized in that the controller (6) is designed to calculate the tolerance deviation in a positively proportional manner to the determined travel speed.
- 8) The trailer (1) according to one of the preceding claims, characterized in that a mechanical brake actuation apparatus is present which is designed to mechanically actuate the braking apparatus if the distance between the trailer (1) and connecting rod (9) falls below a limit distance.

- 9) The trailer (1) according to the preceding claim, characterized in that the mechanical brake actuation apparatus
- comprises a lever (16) that is designed to be flipped by the connecting rod (9) as soon as the distance falls below the limit distance, and
 - comprises a cable (18) that is connected to the braking apparatus and to the lever (16) and is designed to be tensioned by the lever (16) being flipped.
- 10) A method for controlling the distance between
- a trailer (1) with at least one wheel, a wheel drive, and a braking apparatus, and a connecting rod (9) which is designed to be connected to a towing apparatus and which is movably mounted to the trailer (1),
- comprising the steps of
- measuring a position of the connecting rod (9) relative to the trailer (1),
 - measuring a speed of the trailer (1) and/or a speed of the connecting rod (9),
 - determining a travel speed based on the speed of the trailer (1) and/or the speed of the connecting rod (9),
 - controlling the actuation of the wheel drive and/or braking apparatus using a control deviation,
 - characterized in that
 - the position of a neutral point is shifted relative to the trailer (1) proceeding from a zero point with the travel speed,
 - the control deviation is calculated with the distance between the position of the neutral point and the position of the connecting rod.

- 11) The method according to claim 10, characterized in that

- the connecting rod (9) is shifted along its longitudinal axis toward a side nearer the trailer or a side further away from the trailer,
 - the neutral point is shifted proceeding from the zero point, which is located on the longitudinal axis, along the longitudinal axis toward the side further away from the trailer by a correction distance that is positively proportional to the travel speed minus a zero speed.
- 12) The method according to claim 11, characterized in that the correction distance is calculated in a negatively proportional manner to the travel speed if the determined travel speed is less than a start-up speed that is lower than the zero speed.
- 13) The method according to one of claims 10 to 12, characterized in that the wheel drive and/or the braking apparatus are only actuated if the control deviation is greater than a tolerance deviation.
- 14) The method according to the preceding claim, characterized in that the tolerance deviation is calculated in a positively proportional manner to the travel speed.
- 15) The method according to one of claims 10 to 14, characterized in that the braking apparatus is mechanically actuated if the distance between the trailer and connecting rod falls below a limit distance.