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- **RONG, Jigang**
Zhuzhou
Hunan 412007 (CN)
- **JIANG, Zhongsan**
Zhuzhou
Hunan 412007 (CN)
- **LUO, Jun**
Zhuzhou
Hunan 412007 (CN)
- **HUANG, Jiangbiao**
Zhuzhou
Hunan 412007 (CN)
- **XIAO, Xianglong**
Zhuzhou
Hunan 412007 (CN)
- **ZENG, Hui**
Zhuzhou
Hunan 412007 (CN)

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(71) Applicant: **Zhuzhou Times New Material Technology Co., Ltd.**
Zhuzhou, Hunan 412007 (CN)

- (72) Inventors:
- **CHENG, Haitao**
Zhuzhou
Hunan 412007 (CN)
 - **FENG, Wansheng**
Zhuzhou
Hunan 412007 (CN)

(74) Representative: **Keil & Schaaflhausen**
Patent- und Rechtsanwälte PartGmbB
Friedrichstraße 2-6
60323 Frankfurt am Main (DE)

(54) **METHOD FOR IMPROVING OVERALL PERFORMANCE OF RAIL VEHICLE BOGIE AND SUSPENSION DAMPING SYSTEM**

(57) Disclosed are a method for improving overall performance of a rail vehicle bogie and a suspension damping system. The system rigidity of a torque arm node is adjusted by changing and adjusting torque arm node parameters so as to lower the longitudinal rigidity and the deflection rigidity of the torque arm node; meanwhile the axial rigidity is increased, such that a reduction in the torsional rigidity of the torque arm node is avoided. The structure of a vertical stop is changed to lower the vertical rigidity of a primary suspension. The structure of a supporting ball joint of an anti-side-roll torsion bar is changed to prevent the axial movement of the anti-side-roll torsion bar. The structure of a traction ball joint of a traction rod system component is adjusted to control

the non-linear rigidity of the traction ball joint such that the non-linear rigidity of the traction ball joint has a smooth transition. The longitudinal rigidity, axial rigidity, torsional rigidity and deflection rigidity of the entire bogie are adjusted by changing the torque arm node and the vertical stop of the primary suspension system, changing the structure of the supporting ball joint of the anti-side-roll torsion bar of a secondary suspension system and changing the structure of the traction ball joint, such that the overall performance of the bogie is further improved.

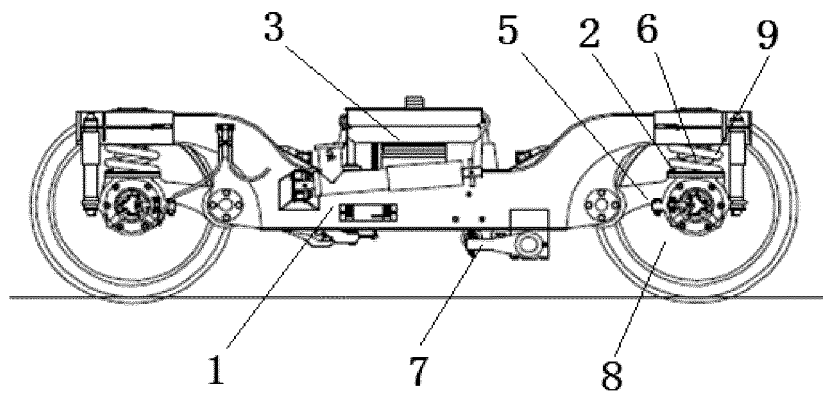


Fig. 1

Description

Technical Field

[0001] The present invention relates to an adjusting method and device for performance of locomotive components, and particularly relates to a method and a bogie system for improving overall performance of secondary suspension bogie of a rail vehicle by changing component structures of a primary suspension system, a secondary suspension system and a traction rod system of the vehicle bogie, so as to enhance the overall performance of a rail vehicle bogie. The present invention belongs to the technical field of manufacturing of critical components.

Background

[0002] A vehicle bogie system is one of the most important components in a rail vehicle structure. Various parameters of the bogie also directly decide vehicle stability and riding comfort of the vehicle. The vehicle bogie is an independent component formed by assembling components and devices of a running part of a locomotive. The vehicle bogie plays the action of supporting a vehicle body, a steering device and a brake, and ensures safe and smooth operation of the locomotive on the track. In addition, the locomotive bogie also plays the action of driving. The components that form the bogie include wheel pairs, an axle box device, a spring suspension device, a basic braking device, a framework or side frame, a swing bolster, etc. A driving device is also arranged on the bogie of the locomotive and a motor car. There are many types of bogies. The bogies can be divided into a two-axle bogie, a three-axle bogie and a multi-axle bogie in accordance with the number of axles; and can be divided into a primary spring suspension bogie and a secondary spring suspension bogie in accordance with the suspension mode of the spring.

[0003] At present, high-speed motor cars in China generally adopt the secondary spring suspension bogie. In recent years, for example, (BST) CRH1A-250 style in China and TGV - A high-speed motor cars in France adopt similar bogies. In this kind of bogie system, the components of the primary suspension system, the secondary suspension system and a traction bar system of the bogie are critical portions of the overall system. The performance of the primary suspension system, the secondary suspension system and the traction bar system directly affects the performance of the whole bogie, wherein the primary suspension system is mounted between a bogie frame of the rail vehicle and an axle box to ensure vertical, transverse and longitudinal stiffness of the primary suspension system and transmit acting force in three directions: vertical direction, longitudinal direction and transverse direction. The locomotive weight above the bogie frame is transmitted to the axle box through an axle box spring of the primary suspension, and then transmitted to wheels and steel rails. The stiffness of transmitting the vertical force by the axle box spring is called as the vertical stiffness of the primary suspension. Pulling force or braking force that acts on the circumference of wheel is transmitted to the axle box. The longitudinal force is then transmitted to the bogie frame through the longitudinal stiffness of an axle box locating device. When the locomotive passes through a curve, the transverse force of the steel rail that acts on the wheel pair is transmitted to the framework through the transverse stiffness of the axle box locating device. The stiffness of the primary suspension in three directions (vertical direction, longitudinal direction and transverse direction) shall be selected appropriately so that the locomotive has good dynamics performance. The device mounted between the bogie frame (or side frame) and the swing bolster (or framework and vehicle body) is called as a swing bolster spring device or a central spring device, and also known as a secondary suspension device. The vertical stiffness or static deflection of the secondary suspension is a very important parameter. The locomotives with a speed above 120km per hour are often provided with a traversing device. In recent years, the spring device between the vehicle body and the bogie is also used as the traversing device and is widely applied. The mass of the vehicle body is supported on the bogie through elastic side bearings on the left side and the right side of the bogie frame. The elastic side bearings are composed of round springs or rubber-metal pads and become the secondary suspensions. The effect of the traversing device is played through the transverse elastic displacement of the elastic side bearings. The traction bar system is a connection apparatus between the vehicle body and the bogie. The traction bar system serves as a bearing apparatus for transmitting gravity, and also serves as a traction apparatus for transmitting longitudinal force. The traction bar system can also transmit transverse force, can realize rotation within a certain range and allows the vehicle body to transverse relative to the bogie within a certain range.

[0004] The above primary suspension system, secondary suspension system and traction bar system bear various loads on the vehicle body and the bogie, wherein the vertical load comprises dead weight and load; transverse load comprises wind power and centrifugal force; and longitudinal load comprises pulling force and braking force. In addition, there are also various dynamic loads caused by vehicle vibration and uneven path, including acting force between wheel tracks, etc. These forces shall be transmitted by the primary suspension system, the secondary suspension system and the traction bar system and shall be alleviated and attenuated. It can be seen that the functional performance of the primary suspension system, the secondary suspension system and the traction bar system have important significance to the guarantee of operation smoothness and safety of the vehicle. But in the existing secondary spring suspension

bogie (such as (BST) CRH1A-250 style bogie in China), it is found in operation that the axle box bearing of the bogie of the secondary suspension system is worn seriously, which results in the damage to the axle box of the whole bogie and seriously affects the dynamics performance of the locomotive. This will greatly influence normal operation of the vehicle and reduce the service life of the vehicle. Therefore, it is necessary to further study on this.

[0005] There is no report about patent literature with the same technology as the present invention through patent retrieval. There are several patents related to the present invention:

1. The PCT patent with the Patent No. of WO2013091319A1 and the title of HIGH SPEED RAILWAY VEHICLE BOGIE. The patent discloses a secondary spring suspension bogie which is a bogie of a high-speed railway train, including a wheel set, a framework, a primary spring suspension system and a secondary spring suspension system, wherein the framework comprises side beams and a middle cross beam. The middle region of each side beam is a mid-concave portion. Both ends of the middle cross beam are respectively connected with the mid-concave portion of the side beam. The primary spring suspension system comprises primary axle box suspension devices. One end of each primary axle box suspension device is connected with the wheel axle of the wheel set, and the other end is supported on one end of one side beam. The secondary spring suspension system comprises at least two spring groups disposed between the side beams at an interval with the middle cross beam. The upper part of the spring group is connected with one carbody. In the bogie of the high-speed railway train used for the present invention, the spring group of the secondary spring suspension system can provide inherent torque of rotational resistance between the framework and the carbody, thereby increasing linear operation stability, curve negotiation performance and critical speed of the railway train.

2. The patent for invention with the patent application No. of CN201110440779.5 and the title of BOGIE OF HIGH-SPEED RAILWAY TRUCK. The patent discloses a bogie of a high-speed railway truck and comprises a framework. Both transverse ends of the framework are respectively connected with one wheel pair through two primary suspension systems. The framework is provided with a secondary suspension system and a basic braking apparatus. The front side and the rear side of the framework are respectively provided with an anti-snakelike vibration reducer. The framework is formed into an H shape and comprises two side beams, one large cross beam and a plurality of small cross beams. The middles of the two side beams are recessed structures. The recessed middle positions of the two side beams are connected through the large cross beam. Both sides of the large cross beam are symmetrically provided with small cross beams respectively connected with the two side beams. Both ends of the side beams are respectively connected with one wheel pair through two primary suspension systems. The framework is provided with a secondary suspension system, a basic braking apparatus and an axle temperature detecting system. The front side and the rear side of the framework are respectively provided with an anti-snakelike vibration reducer.

3. A patent for invention with the Patent No. of FR8420063 and the title of IMPROVEMENTS TO BOGIES OF RAIL VEHICLES. The patent discloses a bogie of a railway locomotive vehicle, which is an improvement of a dual-axle bogie. Especially, to reduce the wear of a wheel axle on a wheel pair on a curve with a small radius, the bogie having a secondary suspension system is provided with elastic longitudinal balance thrust elements of longitudinal balance thrust with the same size and opposite directions on suspension portions of both sides of the main axle of the vehicle. The patent is characterized in that friction damping cushions are disposed around the suspension system and a helical spring. The main axle is provided with the friction damping cushions connected with the suspension portion. The primary suspension realizes connection between axles through hinging elements. In this way, one-axle incline of the longitudinal axle relative to the bogie brings equal two-axle incline relative to the same axle. The adverse effect is played on a friction apparatus, the elastic cushions and the suspension spring that connect two axles.

4. A patent for invention with the patent No. of CN201410755469.6 and the title of "SUBWAY AND BOGIE THEREOF". The patent discloses a subway and a bogie thereof. The bogie comprises: an "H"-shaped framework; two wheel pair axle boxes each comprising a wheel, an axle and an axle box body which is arranged on the framework; a driving device comprising a traction motor rigidly suspended on the framework, and a gear case in transmission connected with the traction motor through a dental coupling, half of the gear case being suspended on the axle and the remaining half being suspended on the framework through a gear case suspender; a basic brake and a brake pad, wherein the basic brake is installed on the side surface of the side beam of the framework, the brake pad is installed on the basic brake and the basic brake acts to enable the brake pad to be close to the pedal surface of the wheel; a primary suspension, wherein each of the wheel pair axle boxes is connected with the framework through the primary suspension and the primary suspension comprises four groups of rubber-metal pad springs; a secondary suspension system comprising an antiroll apparatus, a transverse stopper, an air spring, a height adjusting apparatus structure, a vertical shock absorber and a transverse shock absorber, wherein the antiroll apparatus comprises two vertical bars arranged correspondingly, a torsion bar body connected between the two vertical bars, and a torsion arm, the torsion bar body penetrates through the framework and both ends of the torsion bar body are respectively connected with the vertical bars through the torsion arm; and a traction apparatus comprising a traction seat and a traction bar, wherein one end of the traction bar is connected with a vehicle body through the traction seat and the

other end is connected with the framework.

[0006] Although the above patents involve the secondary suspension bogie and propose some improvements of the secondary suspension bogie, the patents only propose some partial improvements, fail to propose how to integrally change the system structure and especially lack of solutions for improving the overall performance of the rail vehicle bogie by changing component structures of the primary suspension system, the secondary suspension system and the traction bar system. As a result, up to now, the bogie of the secondary suspension still has the problem of serious wear of the axle box bearing and needs to be further studied.

Meanwhile, through the study on the wear of the axle bearing of the secondary suspension bogie, it is found that the wear of the axle bearing occurs mainly because the wheel pair generates great transverse load on the steel rail when the vehicle passes through the curve at high speed. Because the tumbler node is a connecting piece that connects the primary tumbler axle and the bogie framework, the tumbler node has great restrictive effect on the axle box and the bearing in the axle box. If the longitudinal (radial) stiffness of the tumbler node is too large, the transverse load of the wheel pair on the steel rail may be further increased. Meanwhile, the steel rail also generates the same transverse reaction on the wheel pair, thereby wearing rims. Similarly, this transverse load also increases the transverse load of the bearing in the axle box, aggravating the bearing wear in the axle box. Therefore, to reduce the bearing wear in the axle box, it is beneficial to appropriately reducing the longitudinal stiffness of the bogie. But if the longitudinal stiffness of the bogie is reduced greatly, the connection restrictive effect for connecting the axle box and the framework in the bogie is influenced. In this way, the vehicle will generate snakelike motion, thereby reducing smoothness and causing derailment in serious cases. Therefore, how to select appropriate longitudinal (radial) stiffness of the bogie becomes the key to effectively prevent the bearing wear in the axle box. The selection of the longitudinal (radial) stiffness of the bogie depends on the selection of a rate of radial stiffness to axial stiffness (abbreviated as ratio of radial/axial stiffness) to a great extent, and generally limited to about 7:1. However, it is found in study that the bogie takes the secondary suspension system structure, has many combined elements, each component generates an effect on the bogie and eccentricity and displacement after system installation are caused due to accumulated tolerance in combined installation, thereby increasing the deflection load of the bogie. This will cause the problem of the wear of the wheel pair, thereby increasing the wear of the bearing in the axle box. In fact, it is insufficient to consider the ratio of radial/axial stiffness only in determining the design of the ratio of radial/axial stiffness of the bogie currently. In practical application, the bogie is a composite bearing element that bears the radial load, the axial load, the deflection load and the torsional load simultaneously. Therefore, the bogie shall be limited from four aspects of radial direction, axial direction, deflection and torsion.

Technical Problems

[0007] The technical problem of the present invention is to propose a method and a bogie system for improving overall performance of a secondary suspension bogie of a rail vehicle by changing component structures of a primary suspension system, a secondary suspension system and a traction rod system of the vehicle bogie with respect to the problem of easy generation of serious wear of axle box bearing in the existing secondary suspension bogie. The method and the bogie system effectively reduce the wear of the axle box bearing by changing some structures of the primary suspension system, the secondary suspension system and the traction rod system of the vehicle bogie.

Technical Solution

[0008] The present invention provides a method for improving overall performance of a rail vehicle bogie, used to improve overall performance of a secondary suspension bogie of a rail vehicle by changing component structures of a primary suspension system, a secondary suspension system and a traction rod system of the vehicle bogie. The primary suspension system adjusts the longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of a tumbler node by changing parameters of adjusting the tumbler node, so that the longitudinal stiffness and deflection stiffness of the tumbler node are reduced and the transverse load of the vehicle when passing a curve at high speed is reduced. Meanwhile, the axial stiffness is increased to avoid reducing the torsional stiffness of the tumbler node, thereby reducing the wear of an bearing in a axle box. In addition, the vertical stiffness of the primary suspension is reduced by changing the structure of a vertical stopper. In the secondary suspension system, an artiroll torsion bar is prevented from generating axial movement by changing the structure of a fulcrum ball hinge of the artiroll torsion bar. The nonlinear stiffness of a traction ball hinge is controlled by adjusting the structure of the traction ball hinge of the traction rod system component, so that the traction ball hinge alleviates transitional nonlinear stiffness. The longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of the overall bogie are adjusted and the overall performance of the bogie is further improved through the change of the tumbler node and the vertical stopper of the primary suspension system, the structural change of the fulcrum ball hinge of the artiroll torsion bar of the secondary suspension system and the structural change

of the traction ball hinge.

[0009] Further, the longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of the tumbler node are adjusted through the adjustment of the parameters of the tumbler node in a manner of adjusting the rubber layer thickness of the tumbler node, the angle of a rubber layer bevel, the pre-compression amount of the rubber layer and the structural size of a sheath in metal, so that the longitudinal stiffness of the tumbler node is controlled as 11-13 KN.mm⁻¹ and the axial stiffness is controlled as 6-8 KN.mm⁻¹, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box.

[0010] Further, various parameters of the tumbler node are adjusted as follows: firstly, the torsion angle of the tumbler node is computed according to the tumbler length and the vertical deformation of a steel spring; the deflection angle of the tumbler node is computed according to the tumbler length and the transverse deformation of the steel spring; the longitudinal stiffness, the deflection stiffness and the torsional stiffness of the tumbler node are determined according to the torsion angle and the deflection angle of the tumbler node; then, longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness required by the tumbler node are computed by using finite element calculation according to the transverse load and the vertical load of the vehicle; and finally, the rubber layer thickness of the tumbler node, the angle of a rubber layer bevel, the pre-compression amount of the rubber layer and the structural size of a sheath in metal are determined according to the longitudinal stiffness, the deflection stiffness, the torsional stiffness and the axial stiffness of the tumbler node, so that the longitudinal stiffness of the tumbler node is controlled as 11-13 KN.mm⁻¹ and the axial stiffness is controlled as 6-8 KN.mm⁻¹.

[0011] Further, the change of the structure of the vertical stopper to reduce the vertical stiffness of the primary suspension is realized as follows: a frequent-contact type vertical stopper is adopted; the vertical stopper is in a contact state under no load; therefore, relative slip does not occur between a rubber surface and a framework guide barrel; the stiffness of the vertical stopper is set as nonlinear stiffness; front stiffness is small, and rear stiffness is large; in this way, the risk of vehicle derailment is avoided, and the steel spring is protected; and meanwhile, a metal hard stopper (base) is arranged, and has the effect of the vertical stopper.

[0012] Further, the vertical stopper controls the abrupt change of the vertical stiffness by controlling the position of a turning point, realizes a curve pattern of the vertical stiffness of a product by adjusting the height size of a rubber profile, the rubber diameter size, the angle size of the rubber profile and the diameter size of the base, obtains different initial stiffnesses and final stiffnesses by adjusting the rubber diameter size and the rubber angle size, controls the sharp trend of the change of the vertical stiffness and controls the vertical stiffness to change in two-stage to multi-stage stiffness by adjusting the angle size of the rubber profile, and controls the size of the vertical stopper by adjusting the height size of the base.

[0013] Further, the change of the structure of the fulcrum ball hinge of the artiroll torsion bar to prevent the artiroll torsion bar from generating axial movement is realized as follows: the structure of the fulcrum ball hinge of the artiroll torsion bar is adjusted to adjust the torsional stiffness and radial pre-pressure, change the rubber volume, adjust the transverse deformation capability, increase axial and transverse positioning stiffness of the torsion rod and prevent the torsion rod from generating axial movement.

[0014] Further, the artiroll torsion bar is prevented from generating axial movement is realized by adjusting the radius size of the rubber layer of the fulcrum ball hinge of the artiroll torsion bar, changing the pre-compression amount between the rubber of the fulcrum ball hinge and the torsion bar axis, adjusting the torsional stiffness and radial pre-pressure on the premise of guaranteeing longitudinal positioning stiffness (radial stiffness), and adjusting the transverse deformation capability by changing the rubber volume; and simultaneously changing the matching with a bulge corresponding to the torsion bar axis through the adjustment of a slot size and a slot shape of the rubber surface, so as to increase the transverse positioning stiffness (axial stiffness) of the torsion bar axis, thereby preventing the axial movement of the torsion bar.

[0015] Further, the nonlinear stiffness of the traction ball hinge is controlled by adjusting the structure of the traction ball hinge of the traction rod system component is realized as follows: an integral metal jacket is prepressed to press the traction ball hinge in the end part of the traction rod, thereby avoiding the problems of rubber wear, rubber cracking and movement of split-structure metal sheath in the ball hinge during a working cycle due to the adoption of an assembly type split-structure traction ball hinge.

[0016] Further, a metal spindle of the traction ball hinge has a prism structure with an arc spherical surface. The metal jacket is a thin wall metal jacket having a special-shape reinforcing structure (including triangle, trapezoid or arc, etc.). The empty direction of the metal spindle, the empty direction of the metal jacket and the empty direction of a rubber elastomer are matched. A proper reinforcing structure is designed in a transition region of the metal jacket, to offset the reacting force of the elastomer on the metal jacket, thereby preventing the metal jacket from being deformed after forming or during use, and reducing or avoiding the wear of a matching surface during installation or reloading of the product due to an oval phenomenon on the excircle of the matching surface; otherwise, it may influence the product life and component life and even result in the problems of product or component failure, etc.

[0017] A bogie suspension vibration reducing system comprises a primary suspension system, a secondary suspension

system and a traction rod system component. The longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of the tumbler node of the primary suspension system are changed in a manner of adjusting the rubber layer thickness of the tumbler node, the angle of a rubber layer bevel, the pre-compression amount of the rubber layer and the structural size of a sheath in metal, so that the longitudinal stiffness and deflection stiffness of the tumbler node are reduced and the transverse load of the vehicle when passing a curve at high speed is reduced. Meanwhile, the axial stiffness is increased to avoid reducing the torsional stiffness of the tumbler node, such that the longitudinal stiffness of the tumbler node is controlled as $11-13 \text{ KN.mm}^{-1}$ and the axial stiffness is controlled as $6-8 \text{ KN.mm}^{-1}$, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box. Meanwhile, the change of the structure of the vertical stopper to reduce the vertical stiffness of the primary suspension is realized as follows: a frequent-contact type vertical stopper is adopted; the vertical stopper is in a contact state under no load; therefore, relative slip does not occur between a rubber surface and a framework guide barrel; the stiffness of the vertical stopper is set as nonlinear stiffness; front stiffness is small, and rear stiffness is large; in this way, the risk of vehicle derailment is avoided, and the steel spring is protected. In the secondary suspension system, a fulcrum ball hinge with a grooved rubber surface is adopted as the fulcrum ball hinge of the artiroll torsion bar. The fulcrum ball hinge comprises an upper-half cover, a lower-half cover and a rubber sleeve arranged between the upper-half cover and the lower-half cover. The torsion bar penetrates through the rubber sleeve. A tumbler is arranged on one end of the torsion bar, and successively penetrates through the lower-half cover and the upper-half cover and is screwed in a main framework through a connecting bolt. A groove is formed in the inner circumferential surface of the rubber sleeve. The outer circumferential surface of the torsion bar contacts the groove in the inner circumferential surface of the rubber sleeve. The traction ball hinge of the traction rod system alleviates transitional nonlinear stiffness. An integral metal jacket is prepressed to press the traction ball hinge in the end part of the traction rod. The metal spindle of the traction ball hinge has a prism structure with an arc spherical surface. The metal jacket is a thin wall metal jacket having a special-shape reinforcing structure. The empty direction of the metal spindle, the empty direction of the metal jacket and the empty direction of the rubber elastomer are matched. A proper reinforcing structure is designed in the transition region of the metal jacket, to offset the reacting force of the elastomer on the metal jacket, thereby preventing the metal jacket from being deformed after forming or during use.

[0018] Further, the tumbler node is formed by combining two sections of elastic rubber members with symmetric structures, and comprises a left metal jacket and a left metal lining. A left rubber layer is integrally vulcanized between the left metal jacket and the left metal lining. The tumbler node also comprises a right metal jacket and a right metal lining. A right rubber layer is integrally vulcanized between the right metal jacket and the right metal lining. The left rubber layer and the right rubber layer are obliquely arranged in opposite directions. Inner holes of the left metal lining and the right metal lining are respectively taper holes which are arranged in opposite directions, wherein the angle between the bevel and the axis of the left rubber layer and the right rubber layer is $14-28$ degrees; the bevel length of the left rubber layer and the right rubber layer is $35-60 \text{ mm}$; the internal diameter of the tumbler node lining is set as $90-93 \text{ mm}$, and the external diameter is set as $128-132 \text{ mm}$; the internal diameter of the diameter size of the jacket is set as $128-132 \text{ mm}$, and the external diameter is set as $170-173 \text{ mm}$; the matching of the diameter sizes of the tumbler node lining and jacket is ensured so that the longitudinal stiffness of the tumbler node is controlled as $11-13 \text{ KN.mm}^{-1}$ and the axial stiffness is controlled as $6-8 \text{ KN.mm}^{-1}$; and the longitudinal stiffness is controlled to reduce the deflection stiffness, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box.

[0019] Further, the fulcrum ball hinge device comprises an upper-half supporting seat and a lower-half supporting seat. The upper-half supporting seat is fixedly connected to the vehicle framework. The fulcrum ball hinge is disposed between the upper-half supporting seat and the lower-half supporting seat, and successively penetrates through the lower-half supporting seat, the lower-half cover and the upper-half cover and is screwed in the upper-half supporting seat through a connecting bolt, so that the fulcrum ball hinge device is fixedly connected to the vehicle framework.

Beneficial Effects

[0020] After common problems of CRH1A-250 vehicle bogie used in site are repeatedly studied, the present invention finds that the reason is that structures of elastic elements of a bogie suspension system and selection of performance parameters thereof have problems. Firstly, the tumbler ball hinge causes bearing wear due to too large longitudinal stiffness and deflection stiffness. Secondly, the steel spring of the primary suspension is cracked due to too large vertical stiffness of the primary suspension. Thirdly, the fulcrum ball hinge of the artiroll torsion bar causes lateral movement of the bar body. Further, because the traction ball hinge as a ball hinge with hollow or solid structure type, or a joint or a similar flexible connecting product has functional opening in the structural direction, after the product is formed, the ex circle of the matching surface is oval or the excircle of the matching surface of the product is oval during use; and then the matching surface is worn and loses the stiffness, and the product life and component life are influenced. For the above problems, systematic analysis and study are conducted, and reasons of generating the problems are deeply

analyzed, thereby proposing to improve overall performance of a secondary suspension bogie of a rail vehicle by changing component structures of a primary suspension system, a secondary suspension system and a traction rod system of the vehicle bogie. The primary suspension system adjusts the longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of a tumbler node by changing parameters of adjusting the tumbler node, so that the longitudinal stiffness and deflection stiffness of the tumbler node are reduced and the transverse load of the vehicle when passing a curve at high speed is reduced. Meanwhile, the axial stiffness is increased to avoid reducing the torsional stiffness of the tumbler node, thereby reducing the wear of an bearing in a axle box. In addition, the vertical stiffness of the primary suspension is reduced by changing the structure of a vertical stopper. In the secondary suspension system, an artiroil torsion bar is prevented from generating axial movement by changing the structure of a fulcrum ball hinge of the artiroil torsion bar. The nonlinear stiffness of a traction ball hinge is controlled by adjusting the structure of the traction ball hinge of the traction rod system component, so that the traction ball hinge alleviates transitional nonlinear stiffness. The longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of the overall bogie are adjusted and the overall performance of the bogie is further improved through the change of the tumbler node and the vertical stopper of the primary suspension system, the structural change of the fulcrum ball hinge of the artiroil torsion bar of the secondary suspension system and the structural change of the traction ball hinge. The test proves that this can effectively improve the integral structural performance of the bogie on the whole, and effectively reduce the wear of the axle bearing.

Description of Drawings

[0021]

Fig. 1 is a structural schematic diagram of a bogie in an embodiment of the present invention.
 Fig. 2 is a top schematic diagram of a bogie structure in Fig. 1.
 Fig. 3 is a structural schematic diagram of a tumbler node in an embodiment.
 Fig. 4 is a structural schematic diagram of a left node of a tumbler node.
 Fig. 5 is a structural schematic diagram of a fulcrum ball hinge of an artiroil torsion bar in an embodiment.
 Fig. 6 is a structural schematic diagram of a fulcrum ball hinge of an artiroil torsion bar in an embodiment.
 Fig. 7 is a structural schematic diagram of a traction ball hinge in an embodiment.
 Fig. 8 is a structural schematic diagram of a side surface of a traction ball hinge in an embodiment.
 Fig. 9 is a schematic diagram of integral installation of a vertical stopper of a primary suspension in an embodiment.
 Fig. 10 is a structural schematic diagram of a vertical stopper of a primary suspension in an embodiment.
 Fig. 11 is a schematic diagram that the present invention is applied to a specific vehicle bogie.

Detailed Description of Embodiments

[0022] Fig. 1 and Fig. 2 show a specific embodiment of the present invention. A bogie suspension vibration reducing system comprises in a bogie 1 a primary suspension system 2, a secondary suspension system 3 and a traction rod system 4. The longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of the tumbler node 5 of the primary suspension system are changed in a manner of adjusting the rubber layer thickness of the tumbler node, the angle of a rubber layer bevel, the pre-compression amount of the rubber layer and the structural size of a sheath in metal, so that the longitudinal stiffness and deflection stiffness of the tumbler node 5 are reduced and the transverse load of the vehicle when passing a curve at high speed is reduced. Meanwhile, the axial stiffness is increased to avoid reducing the torsional stiffness of the tumbler node, such that the longitudinal stiffness of the tumbler node is controlled as $11-13 \text{ KN} \cdot \text{mm}^{-1}$ and the axial stiffness is controlled as $6-8 \text{ KN} \cdot \text{mm}^{-1}$, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box. Meanwhile, the change of the structure of the vertical stopper 6 of the primary suspension system to reduce the vertical stiffness of the primary suspension is realized as follows: a frequent-contact type vertical stopper is adopted; the vertical stopper 6 is in a contact state under no load; therefore, relative slip does not occur between a rubber surface and a framework guide barrel; the stiffness of the vertical stopper is set as nonlinear stiffness; front stiffness is small, and rear stiffness is large; in this way, the derailment risk of the vehicle 8 is avoided, and the steel spring 9 is protected. In the secondary suspension system, a fulcrum ball hinge with a grooved rubber surface is adopted as the fulcrum ball hinge of the artiroil torsion bar system 7. The fulcrum ball hinge comprises an upper-half cover, a lower-half cover and a rubber sleeve arranged between the upper-half cover and the lower-half cover. The torsion bar penetrates through the rubber sleeve. A tumbler is arranged on one end of the torsion bar, and successively penetrates through the lower-half cover and the upper-half cover and is screwed in a main framework through a connecting bolt. A groove is formed in the inner circumferential surface of the rubber sleeve. The outer circumferential surface of the torsion bar contacts the groove in the inner circumferential surface of the rubber sleeve. The traction ball hinge of the traction rod system 4 alleviates transitional nonlinear stiffness. An integral metal jacket is prepressed to press the traction ball hinge in the end part of the traction rod. The metal spindle

of the traction ball hinge has a prism structure with an arc spherical surface. The metal jacket is a thin wall metal jacket having a special-shape reinforcing structure. The empty direction of the metal spindle, the empty direction of the metal jacket and the empty direction of the rubber elastomer are matched. A proper reinforcing structure is designed in the transition region of the metal jacket, to offset the reacting force of the elastomer on the metal jacket, thereby preventing the metal jacket from being deformed after forming or during use.

Detailed Description

[0023] The present invention is further described below in combination with the drawings and the specific embodiments.

[0024] Fig. 1 and Fig. 2 show schematic diagrams of the present invention. It can be seen from the figures that, the present invention relates to a method for improving overall performance of a rail vehicle bogie, used to improve overall performance of a secondary suspension bogie of a rail vehicle by changing component structures of a primary suspension system, a secondary suspension system and a traction rod system of the vehicle bogie. The primary suspension system adjusts the longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of a tumbler node by changing parameters of adjusting the tumbler node, so that the longitudinal stiffness and deflection stiffness of the tumbler node are reduced and the transverse load of the vehicle when passing a curve at high speed is reduced. Meanwhile, the axial stiffness is increased to avoid reducing the torsional stiffness of the tumbler node, thereby reducing the wear of a bearing in an axle box. In addition, the vertical stiffness of the primary suspension is reduced by changing the structure of a vertical stopper. In the secondary suspension system, an antiroll torsion bar is prevented from generating axial movement by changing the structure of a fulcrum ball hinge of the antiroll torsion bar. The nonlinear stiffness of a traction ball hinge is controlled by adjusting the structure of the traction ball hinge of the traction rod system component, so that the traction ball hinge alleviates transitional nonlinear stiffness. The longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of the overall bogie are adjusted and the overall performance of the bogie is further improved through the change of the tumbler node and the vertical stopper of the primary suspension system, the structural change of the fulcrum ball hinge of the antiroll torsion bar of the secondary suspension system and the structural change of the traction ball hinge.

[0025] The longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of the tumbler node are adjusted through the adjustment of the parameters of the tumbler node in a manner of adjusting the rubber layer thickness of the tumbler node, the angle of a rubber layer bevel, the pre-compression amount of the rubber layer and the structural size of a sheath in metal, so that the longitudinal stiffness of the tumbler node is controlled as 11-13 KN.mm⁻¹ and the axial stiffness is controlled as 6-8 KN.mm⁻¹, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box.

[0026] Various parameters of the tumbler node are adjusted as follows: firstly, the torsion angle of the tumbler node is computed according to the tumbler length and the vertical deformation of a steel spring; the deflection angle of the tumbler node is computed according to the tumbler length and the transverse deformation of the steel spring; the longitudinal stiffness, the deflection stiffness and the torsional stiffness of the tumbler node are determined according to the torsion angle and the deflection angle of the tumbler node; then, longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness required by the tumbler node are computed by using finite element calculation according to the transverse load and the vertical load of the vehicle; and finally, the rubber layer thickness of the tumbler node, the angle of a rubber layer bevel, the pre-compression amount of the rubber layer and the structural size of a sheath in metal are determined according to the longitudinal stiffness, the deflection stiffness, the torsional stiffness and the axial stiffness of the tumbler node, so that the longitudinal stiffness of the tumbler node is controlled as 11-13 KN.mm⁻¹ and the axial stiffness is controlled as 6-8 KN.mm⁻¹.

[0027] The rubber layer thickness of the tumbler node is in inverse proportion to the longitudinal stiffness, the deflection stiffness and the torsional stiffness of the tumbler node as well as the axial stiffness. Refer to an empirical formula:

$$\text{rubber layer thickness} = E_a \cdot E_c \cdot E_t \cdot E_r \cdot 1/(K_a \cdot K_c \cdot K_t \cdot K_r)$$

wherein: E_a -correction factor of elastic modulus of axial stiffness;

E_c -correction factor of elastic modulus of deflection stiffness;

E_t -correction factor of elastic modulus of torsional stiffness;

E_r -correction factor of elastic modulus of longitudinal stiffness;

K_a -axial stiffness of tumbler node;

K_c -deflection stiffness of tumbler node;

K_t -torsional stiffness of tumbler node;

K_r -longitudinal stiffness of tumbler node;

wherein the value range of the radial stiffness E_r is 0.55-0.6; the value range of the axial stiffness E_a is 0.75-0.8; the value range of the deflection stiffness E_c is 0.7-0.75; and the value range of the torsional stiffness E_t is 0.75-0.8.

[0028] The pre-compression amount of the rubber layer of the tumbler node is controlled as 10-12 mm. The lug boss of an inner metal part is prolonged to 5.5-6.5 mm, and a two-section assembly structure is adopted. During assembly, a shell gap of two sections of the tumbler node is adjusted. The pressing force ensures that the pressing load is at least larger than 80 kN or is 3 times of the maximum transverse force, so as to increase the axial stiffness of the tumbler node.

[0029] The bevel angle of the rubber layer of the tumbler node is in inverse proportion to the radial stiffness of the tumbler node and is in direct proportion to the axial stiffness. The relational expression is as follows:

$$\text{the bevel angle of the rubber layer} = E_a \cdot E_r \cdot (K_a / K_r)$$

wherein: E_a -correction factor of elastic modulus of axial stiffness;

E_r -correction factor of elastic modulus of longitudinal stiffness;

K_a -axial stiffness of tumbler node;

K_r -longitudinal stiffness of tumbler node;

wherein the value range of E_a is 1.1-1.3; and the value range of E_r is 0.5-0.6.

[0030] The structure sizes of the metal lining and jacket of the tumbler node include: the internal diameter of the tumbler node lining is set as 90-93 mm, and the external diameter is set as 128-132 mm; the internal diameter of the diameter size of the jacket is set as 128-132 mm, and the external diameter is set as 170-173 mm; the matching of the diameter sizes of the tumbler node lining and jacket is ensured so that the longitudinal stiffness of the tumbler node is controlled as 11-13 KN.mm⁻¹ and the axial stiffness is controlled as 6-8 KN.mm⁻¹, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box.

[0031] The change of the structure of the vertical stopper to reduce the vertical stiffness of the primary suspension is realized as follows: a frequent-contact type vertical stopper is adopted; the vertical stopper is in a contact state under no load; therefore, relative slip does not occur between a rubber surface and a framework guide barrel; the stiffness of the vertical stopper is set as nonlinear stiffness; front stiffness is small, and rear stiffness is large; in this way, the risk of vehicle derailment is avoided, and the steel spring is protected; and meanwhile, a metal hard stopper (base) is arranged, and has the effect of the vertical stopper.

[0032] The vertical stopper controls the abrupt change of the vertical stiffness by controlling the position of a turning point, realizes a curve pattern of the vertical stiffness of a product by adjusting the height size of a rubber profile, the rubber diameter size, the angle size of the rubber profile and the diameter size of the base, obtains different initial stiffnesses and final stiffnesses by adjusting the rubber diameter size and the rubber angle size, controls the sharp trend of the change of the vertical stiffness and controls the vertical stiffness to change in two-stage to multi-stage stiffness by adjusting the angle size of the rubber profile, and controls the size of the vertical stopper by adjusting the height size of the base.

[0033] The change of the structure of the fulcrum ball hinge of the artiroll torsion bar to prevent the artiroll torsion bar from generating axial movement is realized as follows: the structure of the fulcrum ball hinge of the artiroll torsion bar is adjusted to adjust the torsional stiffness and radial pre-pressure, change the rubber volume, adjust the transverse deformation capability, increase axial and transverse positioning stiffness of the torsion rod and prevent the torsion rod from generating axial movement.

[0034] The artiroll torsion bar is prevented from generating axial movement is realized by adjusting the radius size of the rubber layer of the fulcrum ball hinge of the artiroll torsion bar, changing the pre-compression amount between the rubber of the fulcrum ball hinge and the torsion bar axis, adjusting the torsional stiffness and radial pre-pressure on the premise of guaranteeing longitudinal positioning stiffness (radial stiffness), and adjusting the transverse deformation capability by changing the rubber volume; and simultaneously changing the matching with a bulge corresponding to the torsion bar axis through the adjustment of a slot size and a slot shape of the rubber surface, so as to increase the transverse positioning stiffness (axial stiffness) of the torsion bar axis, thereby preventing the axial movement of the torsion bar.

[0035] The nonlinear stiffness of the traction ball hinge is controlled by adjusting the structure of the traction ball hinge of the traction rod system component is realized as follows: an integral metal jacket is prepressed to press the traction ball hinge in the end part of the traction rod, thereby avoiding the problems of rubber wear, rubber cracking and movement of split-structure metal sheath in the ball hinge during a working cycle due to the adoption of an assembly type split-structure traction ball hinge.

[0036] A metal spindle of the traction ball hinge has a prism structure with an arc spherical surface. The metal jacket is a thin wall metal jacket having a special-shape reinforcing structure (including triangle, trapezoid or arc, etc.). The

empty direction of the metal spindle, the empty direction of the metal jacket and the empty direction of a rubber elastomer are matched. A proper reinforcing structure is designed in a transition region of the metal jacket, to offset the reacting force of the elastomer on the metal jacket, thereby preventing the metal jacket from being deformed after forming or during use, and reducing or avoiding the wear of a matching surface during installation or reloading of the product due to an oval phenomenon on the excircle of the matching surface; otherwise, it may influence the product life and component life and even result in the problems of product or component failure, etc.

Embodiment 1

[0037] Embodiment 1 is basically the same as an optical embodiment in structures, but the tumbler node is formed by combining two sections of elastic rubber members with symmetric structures (as shown in Fig. 3 and Fig. 4), and comprises a left metal jacket 12 and a left metal lining 11. A left rubber layer 13 is integrally vulcanized between the left metal jacket 12 and the left metal lining 11. The tumbler node also comprises a right metal jacket 14 and a right metal lining 15. A right rubber layer 16 is integrally vulcanized between the right metal jacket 14 and the right metal lining 15. Inner holes of the left metal lining 11 and the right metal lining 15 are respectively taper holes which are arranged in opposite directions, i.e., a large head of each taper hole is outside and a small head of each taper hole is inside, and the taper holes are close to each other back to back, wherein the internal diameter D1 of the tumbler node lining is set as 90-93 mm, and the external diameter D3 is set as 128-132 mm; the internal diameter D2 of the diameter size of the jacket is set as 128-132 mm, and the external diameter D4 is set as 170-173 mm; the matching of the diameter sizes of the tumbler node lining and jacket is ensured so that the longitudinal stiffness of the tumbler node is controlled as 11-13 KN.mm⁻¹ and the axial stiffness is controlled as 6-8 KN.mm⁻¹, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box.

[0038] Both ends of the rubber layer of the tumbler node lining are inwards dug into a ring of annular groove, wherein the depth size H3 of the groove at one end with a small diameter is controlled as 15-30 mm, the depth size H4 of the groove at one end with a large diameter is controlled as 10-20 mm; the form of digging a complete ring of groove not only reduces the radial stiffness of the tumbler node, but also enhances the axial stiffness of the tumbler node so that the longitudinal stiffness of the tumbler node is controlled as 11-13 KN.mm⁻¹ and the axial stiffness is controlled as 6-8 KN.mm⁻¹, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box. Meanwhile, it is convenient for installation without empty direction.

[0039] The groove is a multi-section deep groove, wherein the first section of groove 17 is a one-sided bevel groove which is concave inwards from a port surface of the rubber layer; in the one-sided bevel groove, one edge is an annular edge parallel to the axis of the tumbler node, and another edge is a first oblique edge which is closed up inwards; the second section of groove 18 is an arc bevel groove having an arc bottom edge. In the arc bevel groove, one edge is a second oblique edge having a slope identical with that of a bevel of the rubber layer of the tumbler node, the second oblique edge is connected with the first oblique edge of the one-sided bevel groove; another edge of the arc bevel groove is an annular edge connected with the annular edge of the one-sided bevel groove; and the annular edge is connected with the second oblique edge through an arc to form the arc bevel groove.

[0040] The annular edge and the first oblique edge of the one-sided bevel groove are covering edges of the rubber layer of the tumbler node. The annular edge and the first oblique edge respectively continue to the end surface of the metal lining and the metal sheath of the tumbler node to form an overall wrap shape.

[0041] The fulcrum ball hinge (as shown in Fig. 5 and Fig. 6) of the bogie comprises an upper-half cover 22, a lower-half cover 23 and a rubber sleeve 24 arranged between the upper-half cover 22 and the lower-half cover 23. The torsion bar penetrates through the rubber sleeve 24. A tumbler is arranged on one end of the torsion bar, and successively penetrates through the lower-half cover 23 and the upper-half cover 22 and is screwed in a main framework through a connecting bolt. A groove 27 is formed in the inner circumferential surface of the rubber sleeve 24. The outer circumferential surface of the torsion bar 21 contacts the groove 27 in the inner circumferential surface of the rubber sleeve. The groove is formed in the inner circumferential surface of the rubber sleeve, so as to reduce the torsional stiffness of the rubber sleeve. When the vehicle body rolls, the rubber sleeve can always conduct torsion together with the torsion bar and the rubber sleeve and the torsion bar may not be loosened, thereby avoiding horizontal movement of the torsion bar. In addition, the notch of the groove is matched with the outer circumferential surface to form a horizontal limiting structure for the torsion bar, thereby increasing the horizontal positioning stiffness of the torsion bar and further limiting the transverse movement of the torsion bar. When the rubber sleeve is compressed, inflated and deformed, the groove formed in the inner circumferential surface of the rubber sleeve can accommodate part of inflated and deformed rubber body, thereby reducing the phenomenon of stress concentration herein and enhancing the service life of the rubber sleeve. The groove is formed in the inner circumferential surface of the rubber sleeve to reduce the torsional stiffness of the rubber sleeve, and the notch of the groove is matched with the outer circumferential surface of the torsion bar to form a limiting structure to prevent the torsion bar from moving transversely. This is realized through improvement on the existing structure without additionally adding components. The purpose of preventing the torsion bar from moving

transversely is achieved, the manufacturing cost is reduced and the installation of the torsion bar is convenient.

[0042] The quantity of the groove 27 is set as one. Each groove 27 is configured to be a continuous groove. The continuous groove is a groove that extends continuously. Each groove 27 is formed in the inner circumferential surface of the rubber sleeve 4 along the circumferential direction, and a plane encircled by each groove 27 is perpendicular to the axis of the torsion bar 21. The above structure is designed. When the torsion bar moves transversely, the effect of limiting the transverse movement of the torsion bar through the groove is better. The rubber sleeve is in a fifty-fifty structure. On the inner circumferential surface of the rubber sleeve, a complete ring of groove is formed along the circumferential direction.

[0043] The cross section of the groove 27 is a semicircle, and can be set into a trapezoid, a rectangle or a triangle herein. The cross section is designed into the semicircle because the semicircle does not have any sharp part and the rubber sleeve may not produce the phenomenon of stress concentration in the sharp part.

[0044] Spacings L are reserved between both ends of the rubber sleeve 24 and between both ends of the upper-half cover 22 and the lower-half cover 23. The spacings L are set as 6 mm to 20 mm. In this way, during operation, when the rubber sleeve is inflated and deformed, both ends of the rubber sleeve are protruded outwards, and the protruding positions of the rubber sleeve generate friction with other fittings, thereby damaging the rubber sleeve. In the present embodiment, the set spacings L can prevent both ends from protruding to the outer parts of the upper-half cover and the lower-half cover when the rubber sleeve is inflated and deformed, thereby avoiding the friction between the protruding positions of the rubber sleeve and other fittings and further enhancing the service life of the rubber sleeve.

Embodiment 2

[0045] Embodiment 2 is basically the same as the optical embodiment in structures, but the fulcrum ball hinge device comprises an upper-half supporting seat and a lower-half supporting seat. The upper-half supporting seat is fixedly connected to the vehicle framework. The fulcrum ball hinge is disposed between the upper-half supporting seat and the lower-half supporting seat, and successively penetrates through the lower-half supporting seat, the lower-half cover and the upper-half cover and is screwed in the upper-half supporting seat through a connecting bolt, so that the fulcrum ball hinge device is fixedly connected to the vehicle framework.

[0046] Both ends of the rubber layer of the tumbler node lining of the bogie are inwards dug into a ring of annular groove, wherein the depth size H3 of the groove at one end with a small diameter is controlled as 15-30 mm, the depth size H4 of the groove at one end with a large diameter is controlled as 10-20 mm; the form of digging a complete ring of groove not only reduces the radial stiffness of the bogie, but also enhances the axial stiffness of the bogie so that the longitudinal stiffness of the bogie is controlled as 11-13 KN.mm⁻¹ and the axial stiffness is controlled as 6-8 KN.mm⁻¹, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box. Meanwhile, it is convenient for installation without empty direction. The groove is a multi-section deep groove, wherein the first section of groove is a one-sided bevel groove which is concave inwards from a port surface of the rubber layer; in the one-sided bevel groove, one edge is an annular edge parallel to the axis of the bogie, and another edge is a first oblique edge which is closed up inwards; the second section of groove is an arc bevel groove having an arc bottom edge. In the arc bevel groove, one edge is a second oblique edge having a slope identical with that of a bevel of the rubber layer of the bogie, the second oblique edge is connected with the first oblique edge of the one-sided bevel groove; another edge of the arc bevel groove is an annular edge connected with the annular edge of the one-sided bevel groove; and the annular edge is connected with the second oblique edge through an arc to form the arc bevel groove. The annular edge and the first oblique edge of the one-sided bevel groove are covering edges of the rubber layer of the bogie. The annular edge and the first oblique edge respectively continue to the end surface of the metal lining and the metal sheath of the bogie to form an overall wrap shape.

[0047] The traction ball hinge of the traction rod system 4 of the bogie alleviates transitional nonlinear stiffness (as shown in Fig. 7 and Fig. 8). An integral metal jacket is prepressed to press the traction ball hinge in the end part of the traction rod. The metal spindle 31 of the traction ball hinge has a prism structure with an arc spherical surface. The metal jacket 32 is a thin wall metal jacket having a special-shape reinforcing structure. The empty direction of the metal spindle, the empty direction of the metal jacket and the empty direction of the rubber elastomer 33 are matched. A proper reinforcing structure 34 is designed in the transition region of the metal jacket, to offset the reacting force of the elastomer on the metal jacket, thereby preventing the metal jacket from being deformed after forming or during use.

[0048] The vertical stopper of the bogie adopts the frequent-contact vertical stopper (as shown in FIG. 9 and FIG. 10). A locating base 44 is fixed above the axle box 45. A dual-coil helical steel spring 42 is arranged above the locating base 44. The steel spring 42 supports the locomotive weight above a bogie frame 46. To reduce the vertical load borne by the steel spring 42 and reduce metal fatigue generated by the steel spring 42 in the operation process of the locomotive to prevent the steel spring 42 from being broken, the vertical stopper 41 is arranged in the steel spring 42. The convex edge of the base of the vertical stopper 41 is abutted against the locating base 44. Because the vertical stopper 41 and the locating base 44 are gyrators, the vertical stopper 41 can be clamped in the locating base 44. A framework guide

barrel 43 is arranged directly above the vertical stopper 41. When the locomotive has no load, the rubber lug boss of the vertical stopper 41 contacts the framework guide barrel 43, and in the whole process of the locomotive from no load to the maximum load, the load of the primary suspension system is supported jointly by the steel spring 42 and the vertical stopper 41, so that the vertical stopper 41 can better reduce the vertical load borne by the steel spring 42.

[0049] The vertical stopper 41 is an axisymmetric gyrator and comprises a rubber body 411, a rubber lug boss 412 and a base 413, while the rubber lug boss 412 comprises a lug boss top 421 and a lug boss outer side 422. The rubber lug boss 412 has a circular table shape. The included angle between the lug boss top 421 and the lug boss outer side 422 is angle A, and the included angle between the first annular flat segment 411 and a horizontal plane is angle B. Angle A and angle B are reduced, so as to increase the range of variable stiffness of the vertical stopper 41. Otherwise, angle A and angle B are increased, so as to reduce the range of variable stiffness of the vertical stopper 41. To reduce consumptive material of the rubber, a concave hole 414 is disposed in the middle position of the bottom of the rubber body 11. The base 413 is embedded into the rubber body 411. Especially, the base body 413 above the convex edge 432 of the base extends into the rubber body 11.

[0050] The above described embodiments only clearly and completely describe the technical solution of the present invention in combination with drawings. Apparently, the described embodiments are merely part of the embodiments of the present invention, not all of the embodiments. Based on the embodiments in the present invention, all other embodiments obtained by those ordinary skilled in the art without contributing creative labor will belong to the protection scope of the present invention.

Industrial Applicability

[0051] After common problems of CRH1A-250 vehicle bogie used in site are repeatedly studied, the present invention finds that the reason is that structures of elastic elements of a bogie suspension system and selection of performance parameters thereof have problems. Firstly, the tumbler ball hinge causes bearing wear due to too large longitudinal stiffness and deflection stiffness. Secondly, the steel spring of the primary suspension is cracked due to too large vertical stiffness of the primary suspension. Thirdly, the fulcrum ball hinge of the artiroll torsion bar causes lateral movement of the bar body. Further, because the traction ball hinge as a ball hinge with hollow or solid structure type, or a joint or a similar flexible connecting product has functional opening in the structural direction, after the product is formed, the ex circle of the matching surface is oval or the excircle of the matching surface of the product is oval during use; and then the matching surface is worn and loses the stiffness, and the product life and component life are influenced. For the above problems, systematic analysis and study are conducted, and reasons of generating the problems are deeply analyzed, thereby proposing to improve overall performance of a secondary suspension bogie of a rail vehicle by changing component structures of a primary suspension system, a secondary suspension system and a traction rod system of the vehicle bogie. The primary suspension system adjusts the longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of a tumbler node by changing parameters of adjusting the tumbler node, so that the longitudinal stiffness and deflection stiffness of the tumbler node are reduced and the transverse load of the vehicle when passing a curve at high speed is reduced. Meanwhile, the axial stiffness is increased to avoid reducing the torsional stiffness of the tumbler node, thereby reducing the wear of an bearing in a axle box. In addition, the vertical stiffness of the primary suspension is reduced by changing the structure of a vertical stopper. In the secondary suspension system, an artiroll torsion bar is prevented from generating axial movement by changing the structure of a fulcrum ball hinge of the artiroll torsion bar. The nonlinear stiffness of a traction ball hinge is controlled by adjusting the structure of the traction ball hinge of the traction rod system component, so that the traction ball hinge alleviates transitional nonlinear stiffness. The longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of the overall bogie are adjusted and the overall performance of the bogie is further improved through the change of the tumbler node and the vertical stopper of the primary suspension system, the structural change of the fulcrum ball hinge of the artiroll torsion bar of the secondary suspension system and the structural change of the traction ball hinge. The test proves that this can effectively improve the integral structural performance of the bogie on the whole, and effectively reduce the wear of the axle bearing.

[0052] Firstly, through the analytical study of many solutions, it is proposed to improve the longitudinal stiffness and the deflection stiffness of the bogie, adjust the positioning of the tumbler type axle box, reduce the transverse load when the vehicle passes through the curve at high speed and prevent or reduce the wear of the bearing in the axle box. The present invention takes two-section type conical composite structure, calculates the torsion angle and the deflection angle of the bogie for determining the longitudinal stiffness and the deflection stiffness of the bogie, and determines the bevel of the bogie through the longitudinal stiffness and the deflection stiffness of the bogie, so as to ensure that angle A between each section of bevel of the bogie and the axis is 14-28 degrees, the length L of the rubber layer is 35-60 mm and the thickness H of the rubber layer is 22-30 mm, thereby ensuring that the axial stiffness of the bogie is controlled as 6-8 KN.mm⁻¹ and the radial stiffness is controlled as 11-13 KN.mm⁻¹, enhancing the axial stiffness of the bogie and reducing the radial stiffness. The test proves that the wear of the bearing in the axle box can be effectively prevented or reduced.

[0053] Secondly, the groove is formed in the inner circumferential surface of the rubber sleeve of the fulcrum ball hinge, so as to reduce the torsional stiffness of the rubber sleeve. Thus, when the vehicle body rolls, the rubber sleeve can always conduct torsion together with the torsion bar and the rubber sleeve and the torsion bar may not be loosened, thereby avoiding horizontal movement of the torsion bar. The notch of the formed groove is matched with the outer circumferential surface of the torsion bar to form a transverse limiting structure of the torsion bar to further limit the transverse movement of the torsion bar. The present invention is realized through improvement on the existing structure without additionally adding components. The purpose of preventing the torsion bar from moving transversely is achieved, the manufacturing cost is reduced and the installation of the torsion bar is convenient. In addition, the formed groove breaks the continuity of the rubber body, thereby reducing the phenomenon of stress concentration when the rubber body is compressed, inflated and deformed and enhancing the service life of the rubber sleeve. The spacings are reserved between both ends of the rubber sleeve and between both ends of the upper-half cover and the lower-half cover, so as to prevent both ends from protruding to the outer parts of the upper-half cover and the lower-half cover when the rubber sleeve is inflated and deformed, thereby avoiding the friction between the protruding positions of the rubber sleeve and other fittings and further enhancing the service life of the rubber sleeve. In the present invention, in the fulcrum ball hinge device, the upper-half supporting seat and the lower-half supporting seat are added, so that the torsion bar can be stably supported and connected to the vehicle framework, thereby better preventing the torsion bar from moving transversely and then ensuring convenient and rapid installation of the torsion bar and increasing the installation efficiency of the artiroll torsion bar. A bulge part is arranged on the outer circumferential surface of the torsion bar, and the bulge part on the outer circumferential surface of the torsion bar is matched with the groove in the inner circumferential surface of the rubber body to form a horizontal limiting structure for the torsion bar, thereby increasing the horizontal positioning stiffness of the torsion bar and further limiting the transverse movement of the torsion bar.

[0054] Further, a frequent-contact type vertical stopper is adopted; the vertical stopper is in a contact state under no load; therefore, relative slip does not occur between a rubber surface and a framework guide barrel; the wear of the product is small and the nonlinear degree of the stiffness of the vertical stopper is high; front stiffness is small, and rear stiffness is large; in this way, the risk of vehicle derailment is avoided, and the steel spring is protected.

Claims

1. A method for improving overall performance of a rail vehicle bogie, **characterized in that** to improve overall performance of a secondary suspension bogie of a rail vehicle by changing component structures of a primary suspension system, a secondary suspension system and a traction rod system of the vehicle bogie. The primary suspension system adjusts the longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of a tumbler node by changing parameters of adjusting the tumbler node, so that the longitudinal stiffness and deflection stiffness of the tumbler node are reduced and the transverse load of the vehicle when passing a curve at high speed is reduced. Meanwhile, the axial stiffness is increased to avoid reducing the torsional stiffness of the tumbler node, thereby reducing the wear of an bearing in a axle box. In addition, the vertical stiffness of the primary suspension is reduced by changing the structure of a vertical stopper. In the secondary suspension system, an artiroll torsion bar is prevented from generating axial movement by changing the structure of a fulcrum ball hinge of the artiroll torsion bar. The nonlinear stiffness of a traction ball hinge is controlled by adjusting the structure of the traction ball hinge of the traction rod system component, so that the traction ball hinge alleviates transitional nonlinear stiffness. The longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of the overall bogie are adjusted and the overall performance of the bogie is further improved through the change of the tumbler node and the vertical stopper of the primary suspension system, the structural change of the fulcrum ball hinge of the artiroll torsion bar of the secondary suspension system and the structural change of the traction ball hinge.
2. The method for improving overall performance of a rail vehicle bogie according to claim 1, **characterized in that** the longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of the tumbler node are adjusted through the adjustment of the parameters of the tumbler node in a manner of adjusting the rubber layer thickness of the tumbler node, the angle of a rubber layer bevel, the pre-compression amount of the rubber layer and the structural size of a sheath in metal, so that the longitudinal stiffness of the tumbler node is controlled as 11-13 KN.mm⁻¹ and the axial stiffness is controlled as 6-8 KN.mm⁻¹, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box.
3. The method for improving overall performance of a rail vehicle bogie according to claim 2, **characterized in that** various parameters of the tumbler node are adjusted as follows: firstly, the torsion angle of the tumbler node is computed according to the tumbler length and the vertical deformation of a steel spring; the deflection angle of the tumbler node is computed according to the tumbler length and the transverse deformation of the steel spring; the

longitudinal stiffness, the deflection stiffness and the torsional stiffness of the tumbler node are determined according to the torsion angle and the deflection angle of the tumbler node; then, longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness required by the tumbler node are computed by using finite element calculation according to the transverse load and the vertical load of the vehicle; and finally, the rubber layer thickness of the tumbler node, the angle of a rubber layer bevel, the pre-compression amount of the rubber layer and the structural size of a sheath in metal are determined according to the longitudinal stiffness, the deflection stiffness, the torsional stiffness and the axial stiffness of the tumbler node, so that the longitudinal stiffness of the tumbler node is controlled as 11-13 KN.mm⁻¹ and the axial stiffness is controlled as 6-8 KN.mm⁻¹.

4. The method for improving overall performance of a rail vehicle bogie according to claim 1, **characterized in that** the change of the structure of the vertical stopper to reduce the vertical stiffness of the primary suspension is realized as follows: a frequent-contact type vertical stopper is adopted; the vertical stopper is in a contact state under no load; therefore, relative slip does not occur between a rubber surface and a framework guide barrel; the stiffness of the vertical stopper is set as nonlinear stiffness; front stiffness is small, and rear stiffness is large; in this way, the risk of vehicle derailment is avoided, and the steel spring is protected; and meanwhile, a metal hard stopper (base) is arranged, and has the effect of the vertical stopper.
5. The method for improving overall performance of a rail vehicle bogie according to claim 4, **characterized in that** the vertical stopper controls the abrupt change of the vertical stiffness by controlling the position of a turning point, realizes a curve pattern of the vertical stiffness of a product by adjusting the height size of a rubber profile, the rubber diameter size, the angle size of the rubber profile and the diameter size of the base, obtains different initial stiffnesses and final stiffnesses by adjusting the rubber diameter size and the rubber angle size, controls the sharp trend of the change of the vertical stiffness and controls the vertical stiffness to change in two-stage to multi-stage stiffness by adjusting the angle size of the rubber profile, and controls the size of the vertical stopper by adjusting the height size of the base.
6. The method for improving overall performance of a rail vehicle bogie according to claim 5, **characterized in that** the change of the structure of the fulcrum ball hinge of the artiroll torsion bar to prevent the artiroll torsion bar from generating axial movement is realized as follows: the structure of the fulcrum ball hinge of the artiroll torsion bar is adjusted to adjust the torsional stiffness and radial pre-pressure, change the rubber volume, adjust the transverse deformation capability, increase axial and transverse positioning stiffness of the torsion rod and prevent the torsion rod from generating axial movement.
7. The method for improving overall performance of a rail vehicle bogie according to claim 6, **characterized in that** the artiroll torsion bar is prevented from generating axial movement is realized by adjusting the radius size of the rubber layer of the fulcrum ball hinge of the artiroll torsion bar, changing the pre-compression amount between the rubber of the fulcrum ball hinge and the torsion bar axis, adjusting the torsional stiffness and radial pre-pressure on the premise of guaranteeing longitudinal positioning stiffness (radial stiffness), and adjusting the transverse deformation capability by changing the rubber volume; and simultaneously changing the matching with a bulge corresponding to the torsion bar axis through the adjustment of a slot size and a slot shape of the rubber surface, so as to increase the transverse positioning stiffness (axial stiffness) of the torsion bar axis, thereby preventing the axial movement of the torsion bar.
8. The method for improving overall performance of a rail vehicle bogie according to claim 1, **characterized in that** the nonlinear stiffness of the traction ball hinge is controlled by adjusting the structure of the traction ball hinge of the traction rod system component is realized as follows: an integral metal jacket is prepressed to press the traction ball hinge in the end part of the traction rod, thereby avoiding the problems of rubber wear, rubber cracking and movement of split-structure metal sheath in the ball hinge during a working cycle due to the adoption of an assembly type split-structure traction ball hinge.
9. The method for improving overall performance of a rail vehicle bogie according to claim 8, **characterized in that** a metal spindle of the traction ball hinge has a prism structure with an arc spherical surface. The metal jacket is a thin wall metal jacket having a special-shape reinforcing structure. The empty direction of the metal spindle, the empty direction of the metal jacket and the empty direction of a rubber elastomer are matched. A proper reinforcing structure is designed in a transition region of the metal jacket, to offset the reacting force of the elastomer on the metal jacket, thereby preventing the metal jacket from being deformed after forming or during use, and reducing or avoiding the wear of a matching surface during installation or reloading of the product due to an oval phenomenon on the excircle of the matching surface; otherwise, it may influence the product life and component life and even result in the

problems of product or component failure, etc.

- 5 10. A bogie suspension vibration reducing system, comprises a primary suspension system, a secondary suspension system and a traction rod system, improves overall performance of a secondary suspension bogie of a rail vehicle by changing component structures of the primary suspension system, the secondary suspension system and the traction rod system, **characterized in that** the longitudinal stiffness, axial stiffness, torsional stiffness and deflection stiffness of the tumbler node of the primary suspension system are changed in a manner of adjusting the rubber layer thickness of the tumbler node, the angle of a rubber layer bevel, the pre-compression amount of the rubber layer and the structural size of a sheath in metal, so that the longitudinal stiffness and deflection stiffness of the tumbler node are reduced and the transverse load of the vehicle when passing a curve at high speed is reduced. Meanwhile, the axial stiffness is increased to avoid reducing the torsional stiffness of the tumbler node, such that the longitudinal stiffness of the tumbler node is controlled as $11-13 \text{ KN.mm}^{-1}$ and the axial stiffness is controlled as $6-8 \text{ KN.mm}^{-1}$, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box. Meanwhile, the change of the structure of the vertical stopper to reduce the vertical stiffness of the primary suspension is realized as follows: a frequent-contact type vertical stopper is adopted; the vertical stopper is in a contact state under no load; therefore, relative slip does not occur between a rubber surface and a framework guide barrel; the stiffness of the vertical stopper is set as nonlinear stiffness; front stiffness is small, and rear stiffness is large; in this way, the risk of vehicle derailment is avoided, and the steel spring is protected. In the secondary suspension system, a fulcrum ball hinge with a grooved rubber surface is adopted as the fulcrum ball hinge of the artiroll torsion bar. The fulcrum ball hinge comprises an upper-half cover, a lower-half cover and a rubber sleeve arranged between the upper-half cover and the lower-half cover. The torsion bar penetrates through the rubber sleeve. A tumbler is arranged on one end of the torsion bar, and successively penetrates through the lower-half cover and the upper-half cover and is screwed in a main framework through a connecting bolt. A groove is formed in the inner circumferential surface of the rubber sleeve. The outer circumferential surface of the torsion bar contacts the groove in the inner circumferential surface of the rubber sleeve. The traction ball hinge of the traction rod system alleviates transitional nonlinear stiffness. An integral metal jacket is prepressed to press the traction ball hinge in the end part of the traction rod. The metal spindle of the traction ball hinge has a prism structure with an arc spherical surface. The metal jacket is a thin wall metal jacket having a special-shape reinforcing structure. The empty direction of the metal spindle, the empty direction of the metal jacket and the empty direction of the rubber elastomer are matched. A proper reinforcing structure is designed in the transition region of the metal jacket, to offset the reacting force of the elastomer on the metal jacket, thereby preventing the metal jacket from being deformed after forming or during use.
- 35 11. The bogie suspension vibration reducing system according to claim 10, **characterized in that** the tumbler node is formed by combining two sections of elastic rubber members with symmetric structures, and comprises a left metal jacket and a left metal lining. A left rubber layer is integrally vulcanized between the left metal jacket and the left metal lining. The tumbler node also comprises a right metal jacket and a right metal lining. A right rubber layer is integrally vulcanized between the right metal jacket and the right metal lining. The left rubber layer and the right rubber layer are obliquely arranged in opposite directions. Inner holes of the left metal lining and the right metal lining are respectively taper holes which are arranged in opposite directions, wherein the angle between the bevel and the axis of the left rubber layer and the right rubber layer is $14-28$ degrees; the bevel length of the left rubber layer and the right rubber layer is $35-60 \text{ mm}$; the internal diameter of the tumbler node lining is set as $90-93 \text{ mm}$, and the external diameter is set as $128-132 \text{ mm}$; the internal diameter of the diameter size of the jacket is set as $128-132 \text{ mm}$, and the external diameter is set as $170-173 \text{ mm}$; the matching of the diameter sizes of the tumbler node lining and jacket is ensured so that the longitudinal stiffness of the tumbler node is controlled as $11-13 \text{ KN.mm}^{-1}$ and the axial stiffness is controlled as $6-8 \text{ KN.mm}^{-1}$; and the longitudinal stiffness is controlled to reduce the deflection stiffness, thereby reducing the transverse load of the vehicle when passing the curve at high speed and reducing the wear of the bearing in the axle box.
- 50 12. The bogie suspension vibration reducing system according to claim 10, **characterized in that** the fulcrum ball hinge device comprises an upper-half supporting seat and a lower-half supporting seat. The upper-half supporting seat is fixedly connected to the vehicle framework. The fulcrum ball hinge is disposed between the upper-half supporting seat and the lower-half supporting seat, and successively penetrates through the lower-half supporting seat, the lower-half cover and the upper-half cover and is screwed in the upper-half supporting seat through a connecting bolt, so that the fulcrum ball hinge device is fixedly connected to the vehicle framework.

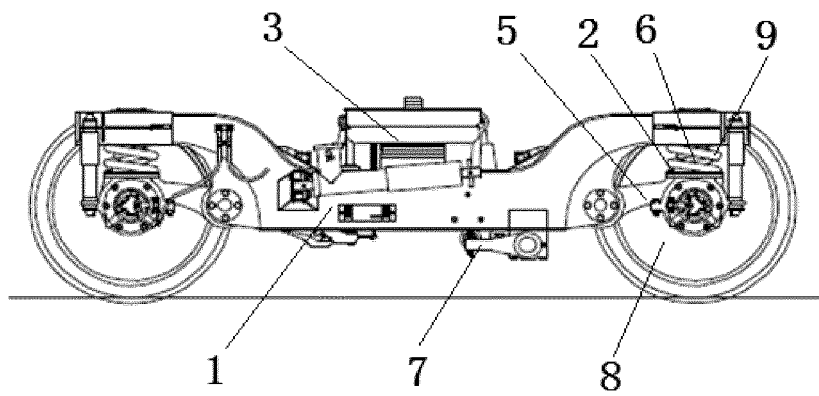


Fig. 1

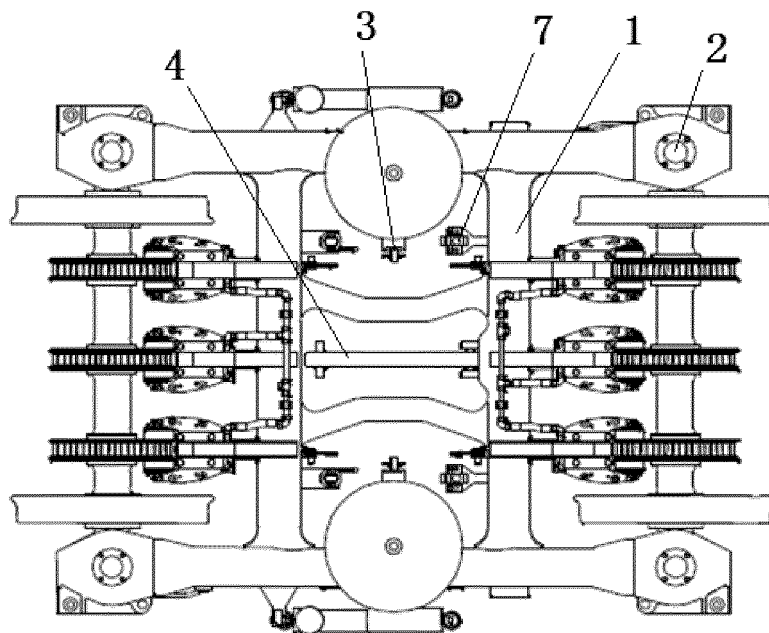


Fig. 2

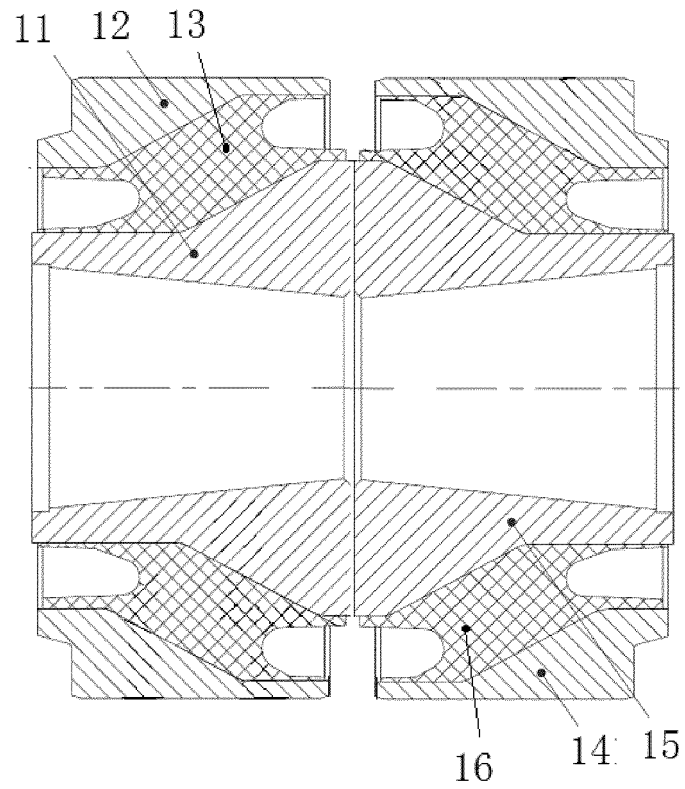


Fig. 3

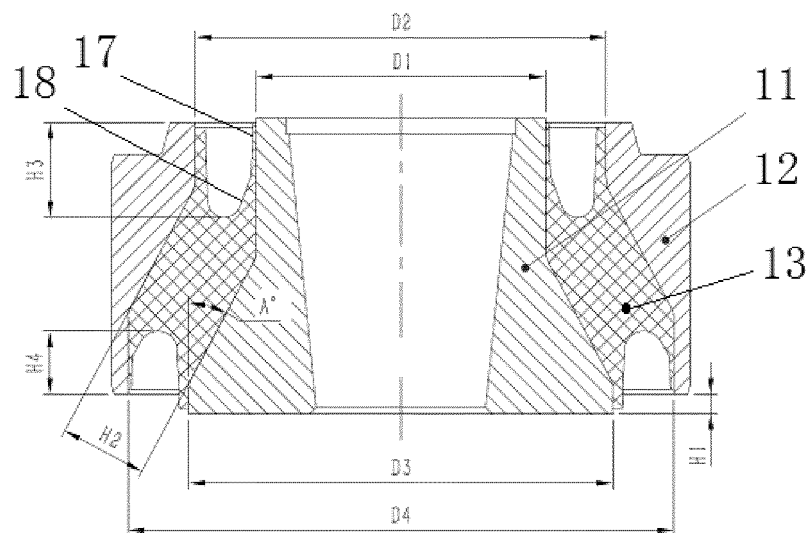


Fig. 4

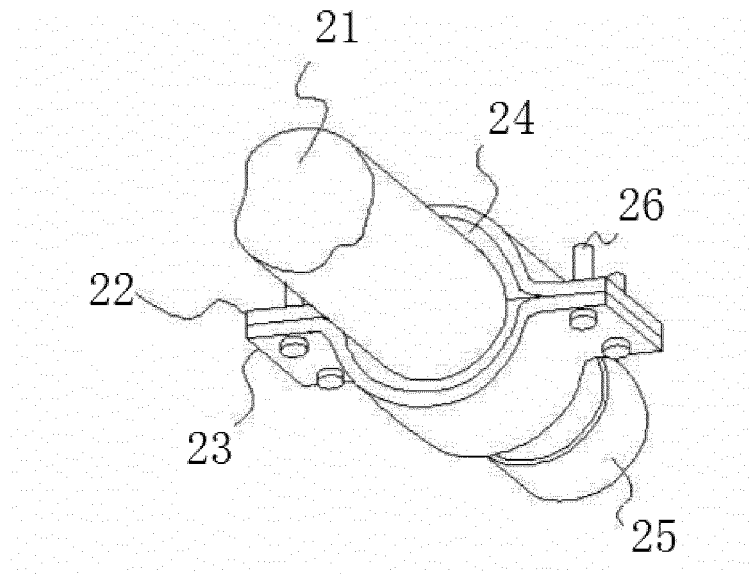


Fig. 5

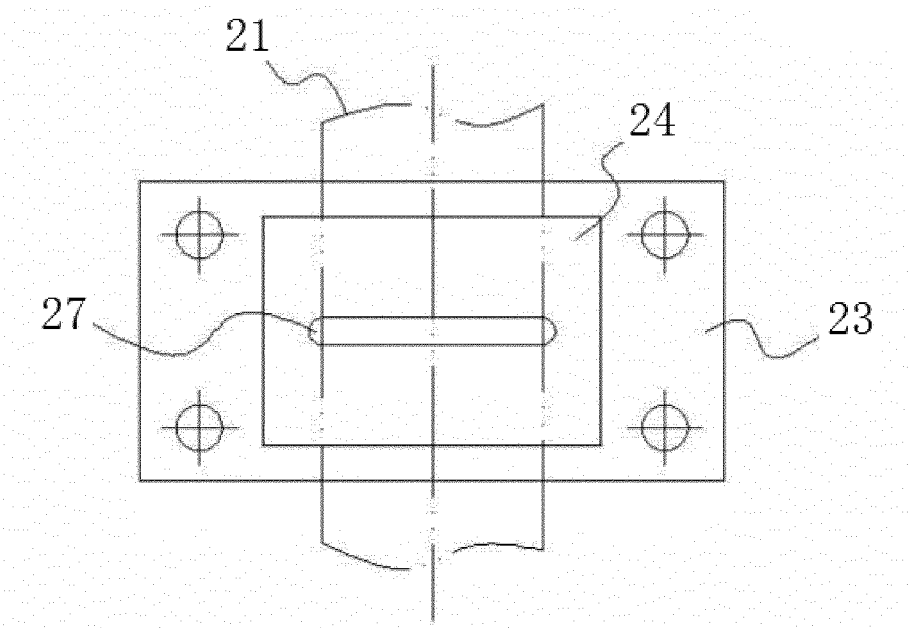


Fig. 6

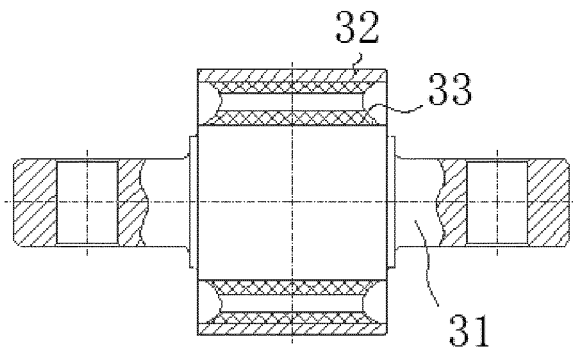


Fig. 7

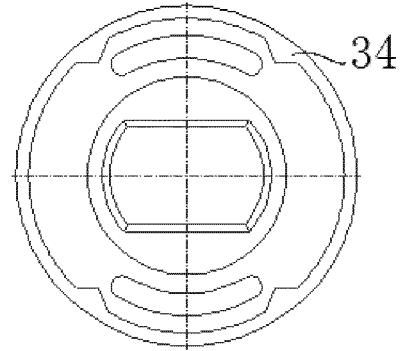


Fig. 8

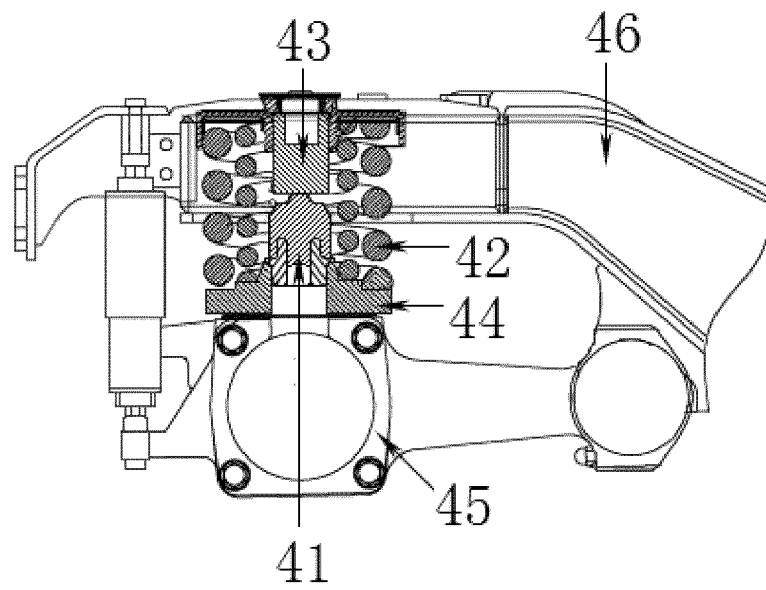


Fig. 9

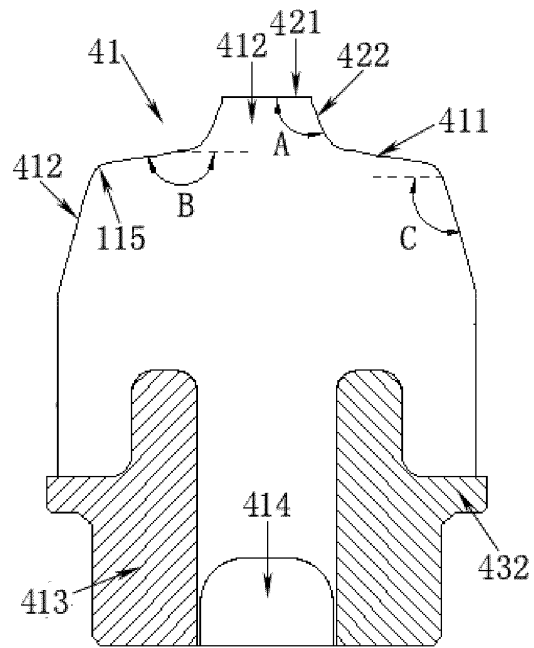


Fig. 10

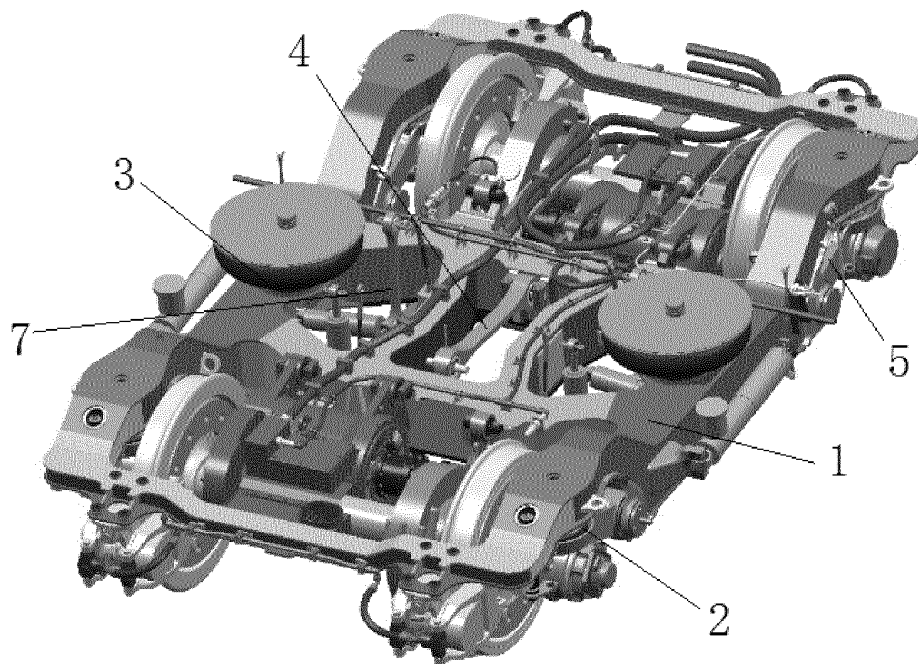


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2016/070656

A. CLASSIFICATION OF SUBJECT MATTER

B61F 5/24 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B61F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT; CNABS; DWPI; EPODOC: anti-rolling, bogie, arm, tumbler, jib, vertical stop, side roll+ resistant, suspension

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 102963382 A (CSR ERQI CO., LTD.), 13 March 2013 (13.03.2013), description, paragraphs [0026]-[0050], and figures 1-13	1-12
A	CN 2797763 Y (ZHUZHOU TIMES NEW MATERIAL TECHNOLOGY CO., LTD.), 19 July 2006 (19.07.2006), the whole document	1-12
A	CN 204713091 U (ZHUZHOU TIMES NEW MATERIAL TECHNOLOGY CO., LTD.), 21 October 2015 (21.10.2015), the whole document	1-12
A	CN 103625494 A (CSR QINGDAO SIFANG CO., LTD.), 12 March 2014 (12.03.2014), the whole document	1-12
A	JP 2015051677 A (HITACHI LTD.), 19 March 2015 (19.03.2015), the whole document	1-12

☐ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 23 July 2016 (23.07.2016)	Date of mailing of the international search report 04 August 2016 (04.08.2016)
Name and mailing address of the ISA/CN: State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No.: (86-10) 62019451	Authorized officer ZHANG, Yingying Telephone No.: (86-10) 62085871

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2016/070656

5	Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
	CN 102963382 A	13 March 2013	None	
10	CN 2797763 Y	19 July 2006	None	
	CN 204713091 U	21 October 2015	None	
	CN 103625494 A	12 March 2014	None	
	JP 2015051677 A	19 March 2015	None	
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Form PCT/ISA/210 (patent family annex) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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- CN 201110440779 [0005]
- FR 8420063 [0005]
- CN 201410755469 [0005]