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(54) **RAILWAY WHEELSET WITH PARTIALLY INDEPENDENT WHEELS**

(57) The railway wheelset described in this patent allows the independent rotation of the wheels while running in curves, while transmitting a predetermined maximum torque between them, keeping said wheels integrals in straight track.

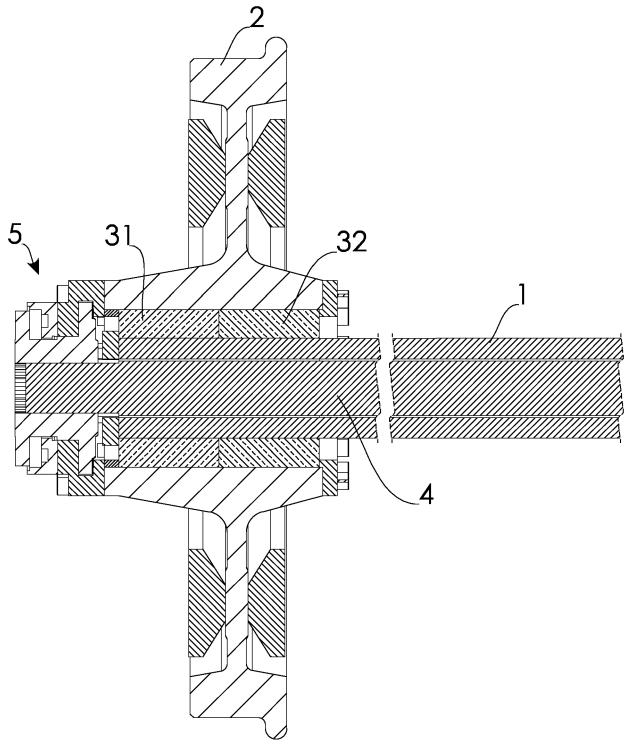

FIG. 2

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Description

Technical field

[0001] This invention belongs to the railway wheelsets field, which traditionally consist of a set of two wheels fitted on a shaft subjected to rotating bending, said axle, and of two bearings embedded within proper castings, also said axleboxes, and mounted at the ends of the axle, also said journals. In detail, this application is about an innovative wheelset whose wheels, in certain conditions, may rotate ad different angular velocities although transmitting torsion up to a maximum predetermined torque.

State of the art

[0002] Differently from road vehicles, wheels belonging to a railway wheelset are both integral with the axle and are therefore forced to run at the same angular speed.

[0003] Although wheel tread profiles are not cylindrical but roughly tapered with a very low conicity, in the order of 1:20 or 1:40, some anomalies appear while negotiating a curve as the "differential effect" is not sufficient to fully compensate the difference in the distance run by the wheels in low radius curves. The differential effect is the phenomenon that happens when the wheelset moves laterally due to the clearance with the track, leading the outer wheel to roll on a greater diameter circle and the inner wheel to roll on a smaller diameter circle, compensating at least partly the aforementioned distance difference.

[0004] As a consequence, all railway vehicles generate in tighter curves the so-called phenomenon of "rail corrugation", i.e. a particular railhead wear pattern which generates high noise levels, high vibration levels and abnormal stresses in both track and rolling stock components.

[0005] To try to reduce corrugation formation, that has a heavy impact on railway lines, several prototypes of bogies equipped with independently rotating wheels were developed. These bogies often provided interesting results when running in curves, nevertheless resulting unsuitable when running in tangent track, when the wheelsets with independently rotating wheels always run laterally shifted, with the wheel flange always in contact with the rail, leading to high wear phenomena which make this solution not advisable.

[0006] It is in fact known that wheelset centring is ensured by longitudinal creep forces that are inherent in conventional wheelsets but that are totally missing in a wheelset with independently rotating wheels.

[0007] The forces that the rail impose any way to the wheels due to the small conicity resulting at the wheel-rail contact, i.e. the so-called "gravitational effect", are not sufficient to centre the wheelset. Moreover, tests conducted in the past have shown the appearance of unexpected vibrations during running in curve of such magnitude to discourage the use of wheelsets with independently rotating wheels on conventional vehicles without re-designing the wheelset suspension devices.

[0008] For such reasons, independently rotating wheels are nowadays only used in trams and the like. These vehicles run at very low speed on very narrow curves and often have a fully low-floor architecture, where the floor is at a height of a few tens of centimetres from the top-of-rail level, this latter condition being impossible for conventional wheelsets where the wheels are connected by a rotating axle.

[0009] As known to the applicant the patent applications EP 0428091 A1 is the only solution including a shaft used to restore the connection of independent wheels and therefore centring. The use of such solutions may nevertheless lead to undesired consequences as shown in papers J.A. Hadden, E.H. Law, Effects of Truck Design on Hunting Stability Of Railway Vehicles, Journal of Engineering for Industry, Transaction of the ASME, 162-171, February 1977 and G.R. Doyle, Jr., R.H. Prause, Hunting Stability of Rail Vehicles with Torsionally Flexible Wheelsets, Journal of Engineering for Industry, Transaction of the ASME, 10-17, February 1977. The critical speed of the vehicle can be reduced to an unacceptable level by the use of a non-sufficiently torsionally stiff shaft; see Fig. 4.

[0010] At the light of these considerations, the aforementioned patent application EP 0428091 A1 omits any consideration on shaft stiffness, that looks not relevant to the application as it is particularly applicable to low-speed low-floor vehicles such as trams. Moreover it must be kept into account that EP 0428091 A1 is only related to driven wheels within a motor wheelset arrangement and it never foresees any direct connection between the wheels, because there is always a differential gearbox between the wheels. Even in Fig. 2 the above said patent application shows a railway driven wheelset with a differential gearbox, i.e. with the wheels which are not directly rotationally connected through a single shaft.

[0011] As a complementary information, the design described in US 2698526 A looks not relevant for the present application as it only discusses a particularly torsionally soft transmission shaft, but the wheels are integral with the axle as in normal wheelset technology.

[0012] Wherever traditional wheelsets are used, i.e. in the vast majority of the applications, the technical problem of preventing rail corrugation is absolutely acknowledged but not solved yet.

[0013] Due to running dynamics characteristics of a vehicle equipped with bogies, the rear wheelset of the front bogie bears the maximum longitudinal forces in mild radius curve, in the order of 1000 ÷ 1500 m, where rolling contact fatigue (RCF) phenomena occur. A conventional wheelset leads the wheel to exert the maximum longitudinal forces on the railhead, leading to extensive RCF phenomena.

[0014] Another limit of conventional wheelset is the need to remove the whole wheelset to perform the most

important maintenance operation of the set, i.e. the exchange of wheels when wear limit of wheel flanges and/or wheel treads is reached.

[0015] About the state of the art of bearings used, journal bearings have been substituted by roller bearings since many decades. Bearings are subjected to vertical and lateral loads, and to such goal the use of so-called *tapered roller bearings units,* marketed under *TBU, TAROL* and other brand names is nowadays general. In these units tapered roller bearings are mounted in a "back-to-back" arrangement that makes the axlebox more firmly connected to the axle in terms on rotations around the longitudinal axis of the vehicle. No other solutions are used in the state-of-the-art to withstand large torques as this longitudinal torsional load is the only one acting on the bearing and subjecting the bearings pair to a torque.

Goals and abstract of the invention

[0016] It must be said that rail corrugation happens in tight curves run at low speed while RCF phenomena happen in mild radius curve run at much higher speed.

[0017] The railway wheelset described in this patent overcomes the technical and performance limits described in the state of the art, allowing to obtain a device which combines the advantages of conventional wheelsets in straight track with the advantages of independently rotating wheelsets in curved track.

[0018] A further goal of the invention is to provide a railway wheelset easily adapted to conventional vehicles, as long as with inboard bearings, which satisfies all technical, normative and safety constraints at an international level. A non secondary advantage is then related to the easiness of disassembly and maintenance.

[0019] The inventive concept fundamentally consists in the use of a fixed bridge to transfer the vertical loads applied to the wheels, which are idle with respect to that bridge but at same time are connected between them through a torsion bar with sufficiently high torsional stiffness which can accommodate for limited rotation difference between the wheels, therefore limiting adverse effects on vehicle dynamics. According to a particularly complete version of the invention, the connection between the wheels can be favourably realized through clutches equipped with torque limiters, suitably pre-loaded and capable to transmit the torsion between the wheels up to a maximum torque that is then maintained during the relative rotation of the wheels. If needed, the pre-determined value of the maximum torque can be varied with known devices.

[0020] More in detail, the wheelset described in this patent includes a non-rotating tubular element, also called bridge, symmetrical with respect to the vertical plane passing through the axis of the track where the wheelset will move on, which is connected to the bogie frame through a suitable suspension stage placed between the wheels and supports the vehicle weight.

[0021] At the ends of said tubular element, or bridge, two wheels are connected with known idling elements, such as roller bearings or the like. Each wheel can be equipped with at least a disc brake. Inside said tubular element, or bridge, a highly torsionally rigid connecting shaft with both ends machined is totally or partly housed. Each end is connected to the respective wheel, in case with a torque limiter clutch joint.

[0022] Another advantage of this invention lies in the fact that said fixes tubular element, or bridge, does not rotate and therefore it is not subjected to rotating bending, resulting in a lighter design compared to the axle of a conventional wheelset. Torsion is in fact transmitted by the stiff connecting shaft that, although designed to transmit the maximum torques that may arise from longitudinal forces at wheel-rail contact, would transmit only the maximum torque defined by the adjustable setting of the clutch which accomplish the function of a torque limiting sliding joint.

[0023] The fixed element, or bridge, does not need to be necessarily cylindrical and may have different shapes and sizes. The connecting shaft is subjected only to torsional loads, being adequately supported; in the solution without clutches such shaft (4) acts as a torsion bar whose high torsional stiffness makes the wheelset very similar to a conventional wheelset.

[0024] When running on winding lines at low speed, as well during running at higher speeds on mild radius curves, the use of the device with clutches with torque limiters is advisable in order to avoid the saturation of the adhesion at the wheel-rail contact and the resulting rail corrugation in tight curves and RCF defects in mild curves.

[0025] With this respect we highlight how the correct functioning of the device is ensured any way by the presence of only one clutch per wheelset, therefore in correspondence of only one of the two wheels of the wheelset.

[0026] We however precise that, even when both wheels are equipped with a clutch, when the torque reaches the limit value only one of the two limiters will intervene, keeping on to transmit only the said predetermined limit torque.

[0027] The presence of two clutches is nevertheless advisable for wheelset symmetry and for redundancy of the torque limiting device reasons. In case the first of the two torque limiters failed to intervene, the second one would it at a slightly higher value.

[0028] In a preferred form of realization, said clutch is of the single plate dry disc type.

[0029] An outstanding advantage of the invention is that a malfunctioning or a failure to one of said devices do not reduce the safety of operations, making the wheelset to behave as a wheelset with independently rotating wheelset and therefore not subjected to undesired dynamic behaviours like hunting.

[0030] Moreover, the differences between the wheels of the innovative wheelset described in this patent and the wheels used in a conventional wheelset are limited to the area connected to the axle as long as they are

mounted on roller bearings or the like. As a consequence, the wheels of the innovative wheelset are interchangeable with the conventional wheels and, advantageously, they are not press or shrink fitted on the axle, thereby avoiding the high stresses that that fitting imply and simplifying assembly operations.

[0031] The wheelset described in this patent allows moreover to continue to use bearing temperature sensors connected to the vehicle logic and able to generate an alarm signal in case of overheating due to roller bearings malfunctioning. About bearings, it is worth to highlight that a further advantage of the invention lies in the greater easiness in roller bearings exchange operations compared to traditional wheelsets with internal bearings where wheels need to be pressed out to reach the bearings.

[0032] Moreover, the wheelset described in this patent may accommodate up to four brake discs, two per wheel, ensuring the highest braking performances.

[0033] A non secondary aim of this invention is to improve the easiness of the wheelset when compared to traditional system. The advantages are evident, as it is sufficient to remove the wheel fasteners, such as bolts or similar, to extract the entire wheel with the bearings set. In case the configuration includes either web-mounted and/or external brake discs, it is sufficient to remove brake callipers and brake cylinders and then extract the wheel. To dismount the whole group only a bearing extractor is needed, without the well known disadvantages related to the traditional technique with pressurized oil that often bring during wheel pressing out to the damage of the coupled surfaces.

[0034] A further goal of this invention is to design a railway wheelset that is compatible with the following braking systems: conventional tread braking, braking with brake discs mounted on the wheel web; braking with brake discs mounted on a specific hub.

Short description of the drawings

[0035]

Figure 1 shows a cross section of one of the two ends of wheelset described in this patent in the configuration with the torsion bar and without the clutch.
In particular one the of the two wheels (2) can be seen, mounted on the outer rings of a pair or roller bearings (31, 32) whose inner rings are fitted on the fixed bridge (1). Inside said bridge (1) the connecting shaft acting as a torsion bar (4) is housed.

Figure 2 shows a cross section of a configuration with a torque limiting clutch.
In particular one the of the two wheels (2) can be seen, mounted on the outer rings of a pair or roller bearings (31, 32) whose inner rings are fitted on the fixed bridge (1). Inside said bridge (1) the connecting shaft (4) is housed; it can be made integral to the wheel by means of the clutch (5).

Figure 3 shows a cross section of a particularly advantageous configuration of the solution shown in the previous figure.
In this figure, in particular, the fixed bridge (1) is designed with a uniform resistance, i.e. with an increased moment of inertia in correspondence with the maximum bending moment.
In particular one the of the two wheels (2) can be seen, mounted on the outer rings of three roller bearings (33, 34 and 35) whose inner rings are fitted on the fixed bridge (1). Inside said bridge (1) the connecting shaft (4) is housed; it can be made integral to the wheel by means of the clutch (5).
In particular in this figure the solution that uses two matched tapered roller bearings arranged face-to-face (34, 35) mounted on the outer side of the wheel (2) and of a thin toroidal roller bearing (33) mounted on the inner side of the wheel (2) is shown. In the figure the barrel shape of the rollers which tolerates large angular and axial misalignments is visible is shown. Moreover, it also has a large basic dynamic load rating. This solution is not used in railway field but is used in other fields of the technology for which the thin toroidal roller bearing (33) was originally developed.

Figure 4 shows a chart, derived from paper by G.R. Doyle, illustrating the reduction of critical speed when the torsional stiffness of the axle (shaft) is reduced. The curve in the graph indicates the critical speed, in km/h, as a function of an adimensional stiffness calculated as the ratio with respect to a stiffness of 3.06 MNm/rad.

Detailed description of a configuration of the invention

[0036] In the configuration that is described hereinafter the wheelset object of this patent shows a hollow pipe fixed bridge (1), a particularly simple and practical solution as it allows to use easily available semifinished products.

[0037] We remind anyhow that, favourably, in the wheelset described in this patent this element is not subjected to torsional stresses that are supported by the connecting shaft (4) instead.

[0038] The connecting shaft (4) is coaxial with wheels (2) and with the roller bearings through which the wheels are rotationally connected to the fixed bridge (1).

[0039] In the configuration described here, the shaft (4) and the two wheels (2) are connected through two suitable clutches (5) with torque limiters preset at the same limit value.

[0040] Friction reduction systems (3) can be of different nature and are generally known devices. Quite simply two tapered roller bearings can be used, but the solution that has shown the best combination in terms of compactness, load supporting capacity and life cycle duration foresees the use of:

- on the outer side of the wheel (2), a pair of matched tapered roller bearings arranged face-to-face (34, 35), which acts as a hinge, supporting both axial and radial loads;
- on the inner side of the wheels (2), a thin toroidal roller bearing (33), for example the CARB® bearing manufactured by SKF®, which acts as a support, supporting only radial loads.

[0041] This solution satisfies the following requirements: it uses mass-produced components such as in particular the roller bearings; it has a load capacity sufficient to last more than 2 million kilometres with an axial load of 20 tonnes; the classical layout of a shaft resting on hinge and support is realized; used roller bearings have performances suitable for use in high-speed applications; overall size is reasonable in both axial and radial directions; machining results simple and low cost.

[0042] Although the proposed layout is widely used in gearboxes, it is innovative in the railway wheelset field as it has never been used in this field and is not part of the knowledge of the expert in this area.

[0043] This roller bearings arrangement particularly consists in a locating bearing (tapered roller bearings paired in a face-to-face arrangement) and in a non-locating bearing (CARB® toroidal roller bearing).

[0044] This arrangement is not part of the state-of-the-art as long as conventional wheelsets use axleboxes equipped with different solutions, i.e. back-to-back tapered roller bearings, cylindrical roller bearings, self-aligning spherical bearings, etc., while independently rotating wheels always use back-to-back tapered roller bearings.

[0045] This innovative layout is necessary for the solution disclosed by this patent application, as in this application high applied loads require larger bearings and a different arrangement.

[0046] In a different embodiment of this railway wheelset the rotating shaft (4) is connected to both said wheels (2) and acts as a torsion bar.

[0047] In a preferred embodiment the stiffness of said rotating shaft (4) is comprised between 0.4 MNm/rad and 4.0 MNm/rad. Preferably the above mentioned friction reduction mechanisms (3) comprise roller bearings, including at least a toroidal roller bearing (33), like the CARB® roller bearing, mounted on the inner side of said wheel (2) and a pair of matched tapered bearings (34, 35) arranged face-to-face in the outer part of said wheel (2).

Claims

1. A railway wheelset including a fixed bridge (1), defining an axis of rotation, at whose ends two wheels (2) are connected through proper friction reduction mechanisms (3), **characterized in that** it comprises a rotating connecting shaft (4), connected to both said wheels (2) and with them coaxial to said axis of rotation, said shaft (4) being connected to at least one of said wheels (2) through a clutch (5).

2. A railway wheelset as set forth in the previous claim **characterized in that** both said wheels (2) are integral to said rotating shaft (4) each through a dedicated clutch (5).

3. A railway wheelset as set forth in one or more of the previous claims **characterized in that** at least one of said clutches (5) is installed outside at least one of said wheels (2).

4. A railway wheelset as set forth in one or more of the previous claims **characterized in that** said at least one clutch (5) is provided with a torque limiting mechanism which prevents a predetermined torque value to be overcome.

5. A railway wheelset as set forth in the previous claim **characterized in that** said predetermined torque limit of said torque limiter can be varied by means of known arrangements.

6. A railway wheelset as set forth in one or more of the previous claims **characterized in that** at least one of said clutches (5) can be locked.

7. A railway wheelset as set forth in one or more of the previous claims **characterized in that** at least one of said torque limiters can be locked.

8. A railway wheelset as set forth in one or more of the previous claims **characterized in that** said proper friction reduction mechanisms (3) comprise roller bearings, including at least a toroidal roller bearing (33), like the CARB® roller bearing, mounted on the inner side of said wheel (2) and a pair of matched tapered bearings (34, 35) arranged face-to-face in the outer part of said wheel (2).

9. A railway wheelset as set forth in one or more of the previous claims **characterized in that** said at least one clutch (5) is of single plate dry disc clutch type.

10. A railway wheelset including a fixed bridge (1), defining an axis of rotation, at whose ends two wheels (2) are connected through proper friction reduction mechanisms (3), **characterized in that** a rotating shaft (4) is connected and coaxial to both said wheels (2) and with them coaxial to said axis of rotation and acts as a torsion bar.

11. A railway wheelset as set forth in the previous claim 10 **characterized in that** the stiffness of said rotating shaft (4) is comprised between 0.4 MNm/rad and 4.0 MNm/rad.

12. A railway wheelset as set forth in one or more of the previous claims 10 to 11, **characterized in that** said proper friction reduction mechanisms (3) comprise roller bearings, including at least a toroidal roller bearing (33), like the CARB® roller bearing, mounted on the inner side of said wheel (2) and a pair of matched tapered bearings (34, 35) arranged face-to-face in the outer part of said wheel (2).

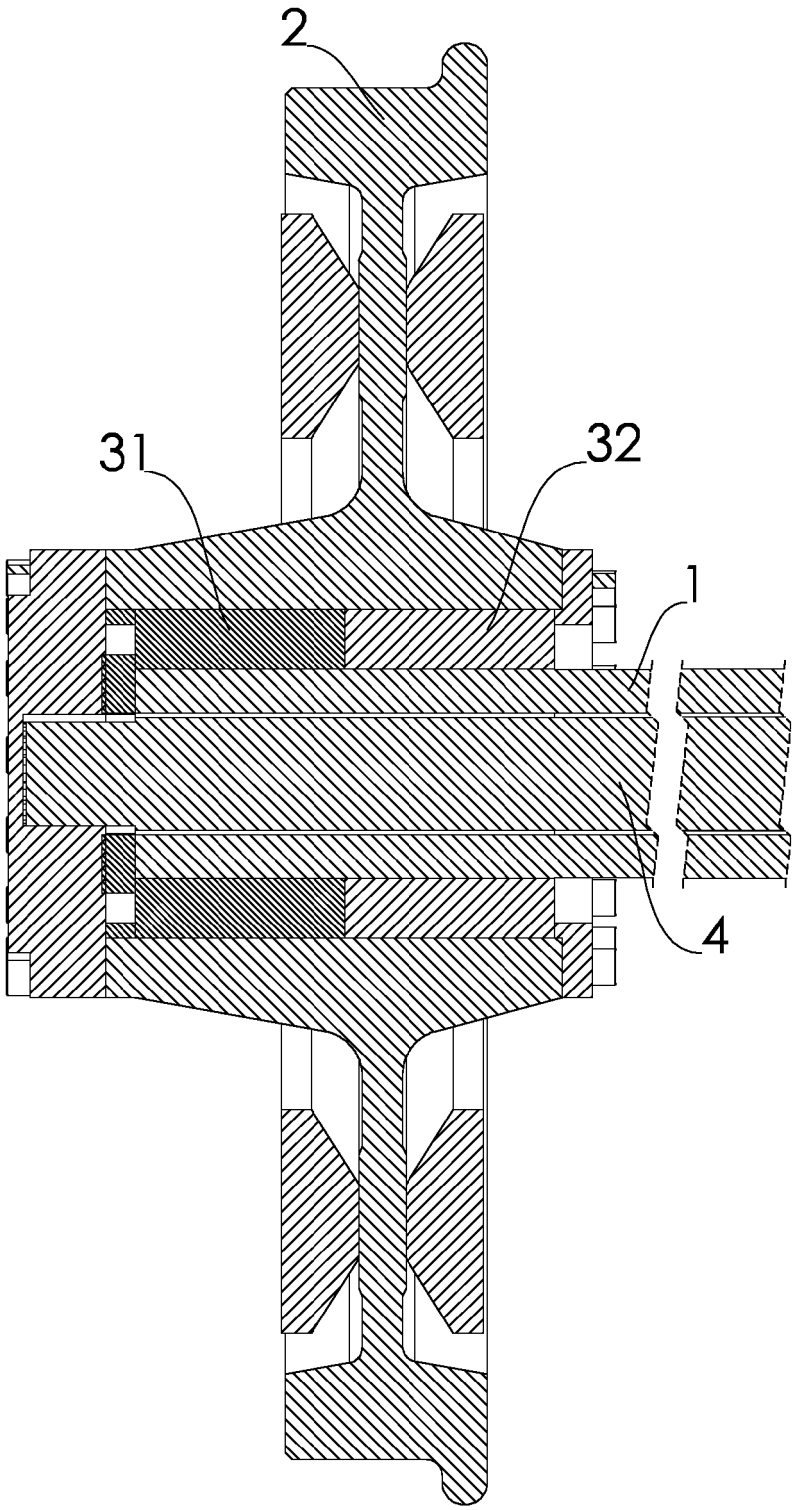

FIG. 1

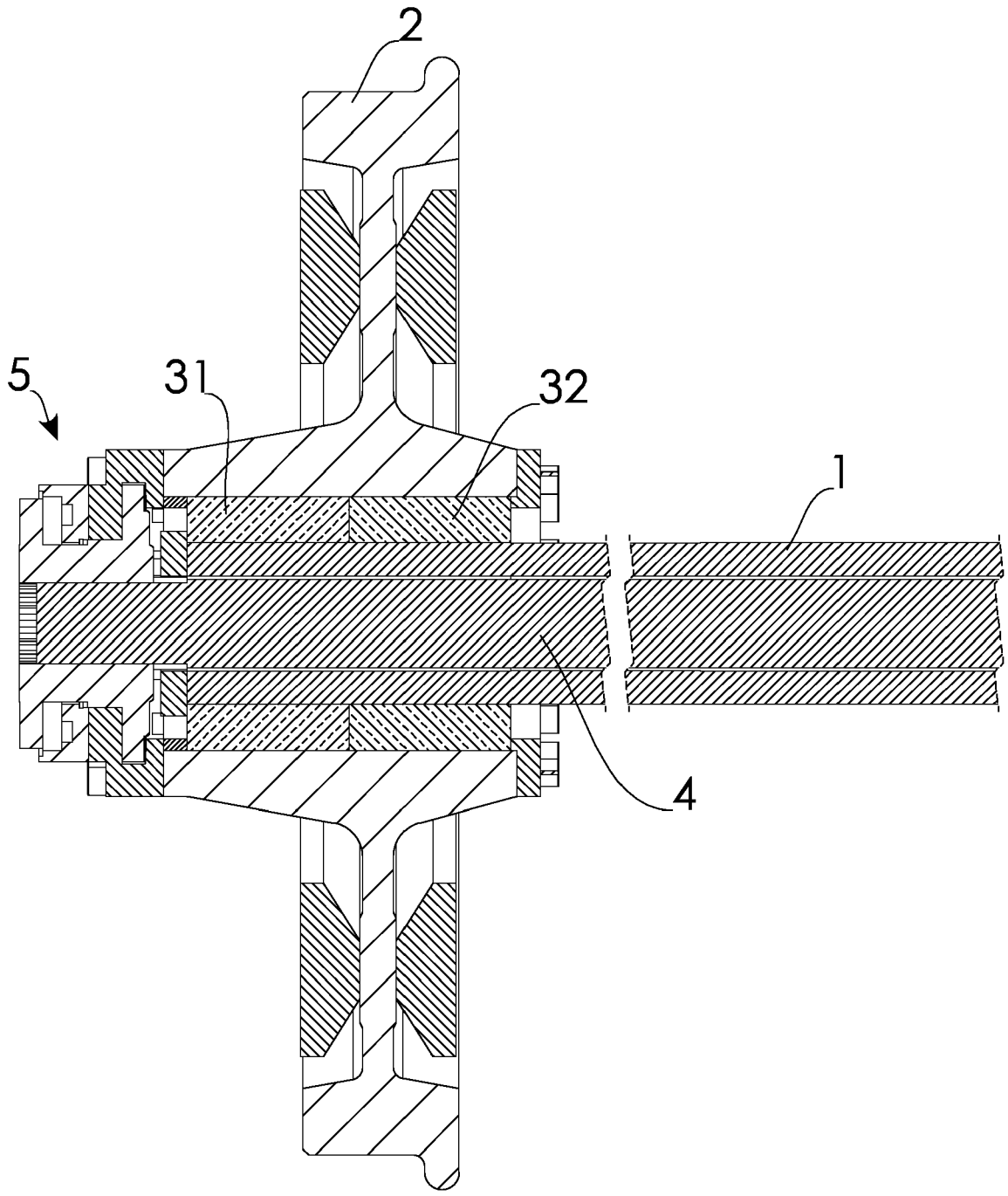

FIG. 2

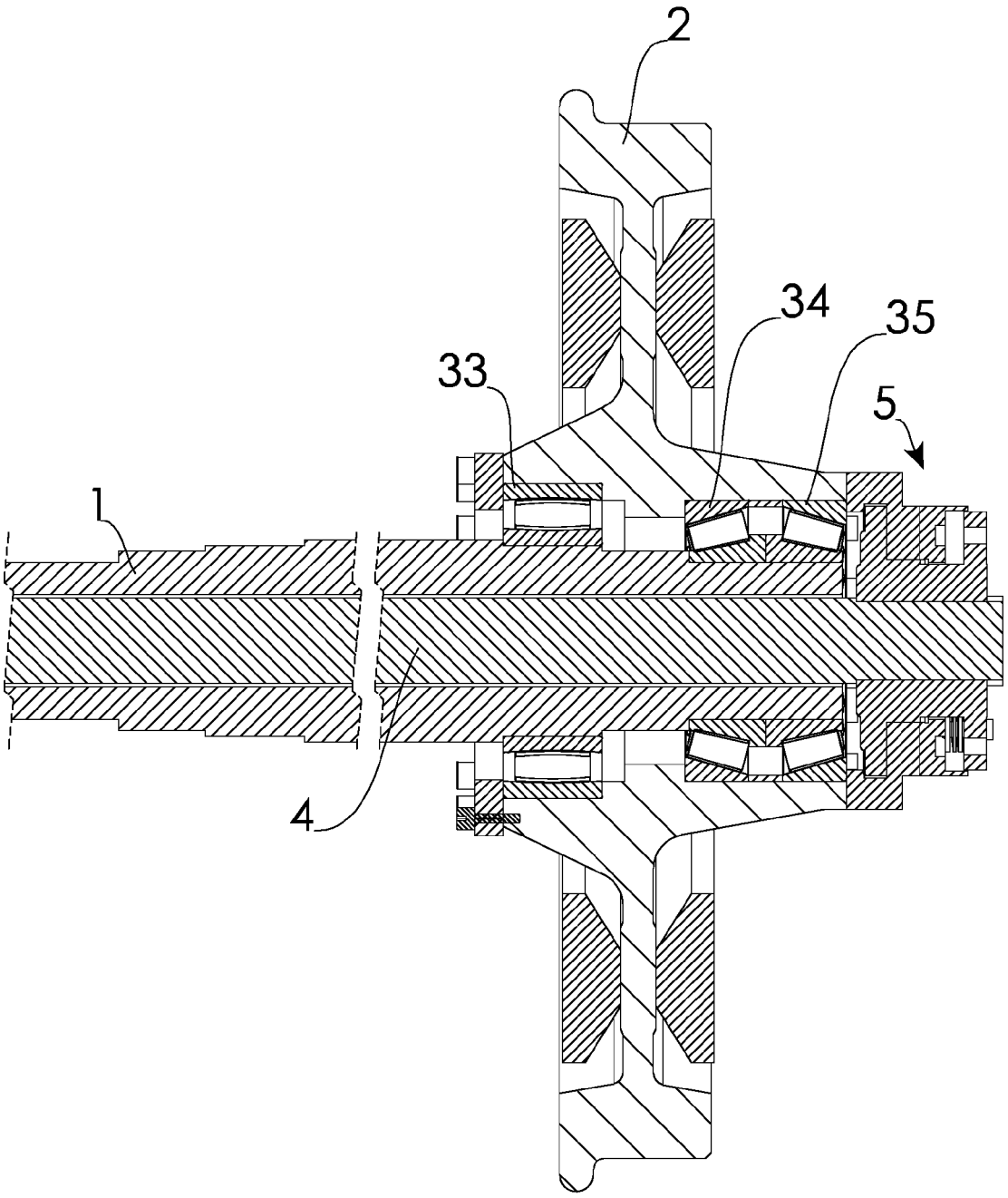

FIG. 3

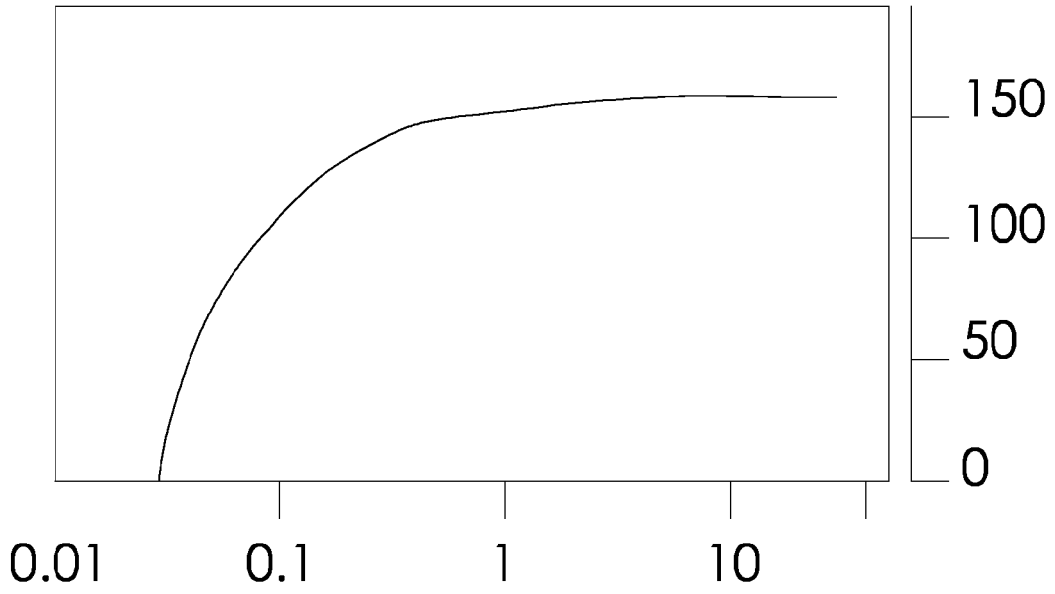

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 15 17 3213

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

B61F
B61C
B60B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	27 August 2015	Lorandi, Lorenzo

CATEGORY OF CITED DOCUMENTS

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27-08-2015

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REFERENCES CITED IN THE DESCRIPTION

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