



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
16.08.2017 Bulletin 2017/33

(51) Int Cl.:
B61F 5/38 (2006.01) B61F 5/30 (2006.01)

(21) Application number: **16155620.4**

(22) Date of filing: **15.02.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

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(54) **WHEEL AXLE GUIDING ASSEMBLY WITH LONGITUDINAL HYDRO-MECHANICAL CONVERTERS AND ASSOCIATED RUNNING GEAR**

(57) The invention relates to a wheel axle guiding assembly (10) comprising an axle box carrier (20), an axle box (14) located longitudinally between a front part (16) and a rear part (18) of the axle box carrier (20); a front longitudinal hydro-mechanical converter (32) between a front part (16) of an axle box carrier (20) and a rear longitudinal hydro-mechanical converter (34) between the axle box (14) and a rear part (18) of the axle box carrier (20) to allow a fore-and-aft movement of the axle box (14) relative to the axle box carrier (20) parallel to a longitudinal direction (200). Each of the front and

rear longitudinal hydro-mechanical converters (32, 34) includes a housing (36), a plunger (38) and an elastomeric body (40) fixed to the housing (36) and to the plunger (38) so as to allow a fore-and-aft relative movement parallel to the longitudinal direction (200) between the plunger (38) and the housing (36), a single variable volume hydraulic chamber (42) being formed between the housing (36), the plunger (38) and the elastomeric body (40). A hydraulic port (54) provides a connection of the variable volume hydraulic chamber (40) with an external hydraulic circuit (54, 56, 64, 66, 68, 70, 72, 74).

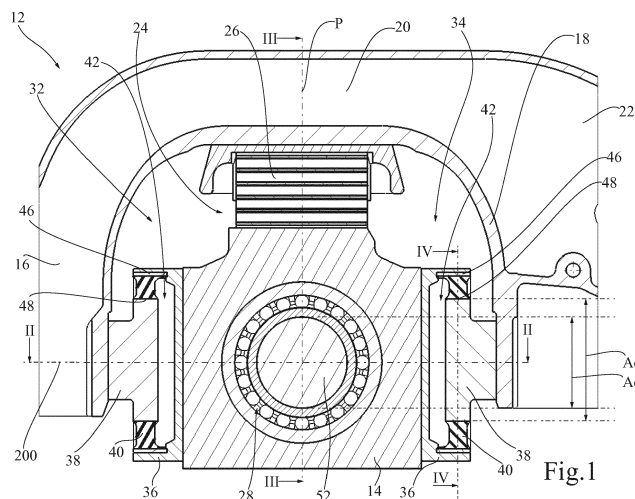


Fig.1

Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to a wheel axle guiding assembly and to a running gear for a rail vehicle.

BACKGROUND ART

[0002] A two-axle bogie for a rail vehicle described in DE 31 23 858 C2 is provided with a wheel axle guiding assembly comprising: a pair of front left hydraulic cylinders for moving the left wheel of the front wheel set towards and away from a median transverse vertical plane of the bogie, a pair of front right hydraulic cylinders for moving the right wheel of the front wheel set towards and away from the median transverse vertical plane, a pair of rear left hydraulic cylinders for moving the left wheel of the rear wheel set towards and away from the median transverse vertical plane, a pair of rear right hydraulic cylinders for moving the right wheel of the rear wheel set towards and away from the median transverse vertical plane, and hydraulic connection to ensure that movements of the left, respectively right wheels of the front wheel set towards, respectively away from the median transverse vertical plane result in movements of the left, respectively right wheels of the front wheel set towards, respectively away from the median transverse vertical plane. In other words, the steering of the front and rear wheel sets is coordinated to negotiate tight curves of the track.

[0003] It has been suggested in EP1228937 to provide a bogie with specific bushings each mounted between one of the axle boxes and the bogie frame, said bushings comprising a cylindrical outer case, a bolt coaxially received within the outer case, and an elastomer body connecting the outer case to the bolt so as to form two chambers, which are located between the outer case and the bolt on opposite sides of the bolt. The two opposite chambers are filled with fluid. A fluid path is formed between the two chambers to allow a fore-and-aft movement of the bashing axle within the outer case. Further fluid connections may be provided to interconnect the chambers of the different bushings with a pressure source to constitute an active steering system. Due to the shape of the bushing, the amount of elastomer is limited, as well as the pumping area. As a result the effectiveness and lifespan of these specific bushings is limited.

[0004] A similar bashing is disclosed in EP1457706. In order to obtain a stiffness that varies with the frequency, an arcuate channel is provided between the two chambers of the bashing. The frequency response of the bashing depends on the pumping area, as well as on the length and cross-section of the channel and, for a given set of parameters, the stiffness increases with the frequency. However, due to its size, the capabilities of the bashing are limited.

[0005] A running gear unit for a rail vehicle, having a

running gear frame, supported on a pair of wheel sets via a primary suspension system is disclosed in WO2014170234. The two wheel sets are coupled with one another via a coupling arrangement in such a way that a first transverse displacement of the first wheel set with respect to the running gear frame in the transverse direction results in a second, identically directed transverse displacement of the second wheel set with respect to the running gear frame in the transverse direction. Concurrently, the coupling arrangement is such that a first rotation of the first wheel set with respect to the running gear frame about a vertical axis results in a second rotation in the opposite direction of the second wheel set with respect to the running gear frame. The coupling arrangement comprises bushings each comprising a cylindrical outer case, a bolt coaxially received within the outer case, and an elastomer body connecting the outer case to the bolt so as to form four chambers. Due to their size, the capabilities of the bushings are limited.

[0006] A primary suspension system disclosed in US4932330 includes a pair of spaced vertical springs connected between a journal bearing retainer and a side frame of a railway truck. Pairs of angularly disposed elastomeric springs are also connected between a lower support housing and opposite angular ends of the journal bearing retainer to provide lateral and longitudinal stiffness. However, these elastomeric springs do not provide a frequency dependent stiffness.

SUMMARY OF THE INVENTION

[0007] The invention aims to provide wheel axle guiding assemblies with more robust hydro-mechanical converters that provide long strokes and improved capabilities, within the space requirement of conventional running gears.

[0008] According to a first aspect of the invention, there is provided a wheel axle guiding assembly comprising:

- an axle box defining a horizontal revolution axis and a longitudinal horizontal direction perpendicular to the revolution axis;
- an axle box carrier, the axle box being located longitudinally between a front part and a rear part of the axle box carrier; and
- a front longitudinal hydro-mechanical converter fixed to the axle box and the front part of the axle box carrier and a rear longitudinal hydro-mechanical converter fixed to the axle box and the rear part of the axle box carrier to allow a fore-and-aft movement of the axle box relative to the axle box carrier parallel to the longitudinal direction; wherein each of the front and rear longitudinal hydro-mechanical converters includes a housing, a plunger and an elastomeric body fixed to the housing and to the plunger so as to allow a fore-and-aft relative movement parallel to

the longitudinal direction between the plunger and the housing, a single variable volume hydraulic chamber being formed between the housing, the plunger and the elastomeric body, each of the front and rear longitudinal hydro-mechanical converters further including a hydraulic port for connecting the variable volume hydraulic chamber to an external hydraulic circuit.

[0009] As one hydro-mechanical converter is provided on each side of the axle boxes and each hydro-mechanical converter is provided with a single variable volume chamber between the plunger and the housing, more room is available for each variable volume chamber than the prior art. Both the effective pumping area and the stroke of the hydro-mechanical converters can be increased. The larger effective pumping area and a larger size of the elastomeric body are predominant factors for defining a stiffer dynamic response, which takes advantage from a large pumping area, and a greater ratio between the dynamic stiffness and the static stiffness of the wheel axle guiding assembly.

[0010] Preferably the axle box houses a bearing having an inner diameter defining a cross-sectional area A_{Φ} of an end of a wheel axle to be received in the bearing and the plunger has an effective area A_e measured in a plane perpendicular to the longitudinal direction, which is greater than half the cross-sectional area A_{Φ} , preferably greater than the cross-sectional area A_{Φ} .

[0011] The elastomeric body is annular, preferably with a circular, elliptic or rectangular cross-section between the plunger and the housing. According to a preferred embodiment and in order not to overstress the elastomeric body, the elastomeric body can be fixed to an annular cylindrical or frusto-conical surface of the housing facing the plunger and an annular cylindrical or frusto-conical surface of the plunger facing the housing.

[0012] Preferably, each of the front and rear longitudinal hydro-mechanical converters has a longitudinal stiffness, which increases with a frequency of the fore-and-aft movement of the axle box relative to the axle box carrier from a quasistatic stiffness value to a dynamic stiffness value, wherein the plunger and the elastomeric body have dimensions such that a ratio R of the dynamic stiffness value to the quasistatic stiffness value is greater than 10, preferably greater than 20, preferably greater than 50. As a result, the wheel axle guiding assembly has a soft response to quasistatic longitudinal loads, in particular passive steering movement, and simultaneously efficiently counteracts hunting oscillations at higher frequencies.

[0013] An abutment may be provided between the plunger and the housing for limiting a contraction movement of the plunger. In order to increase comfort, the abutment is preferably provided with an elastomeric buffer.

[0014] According to a preferred embodiment, the wheel axle guiding assembly further comprises a vertical

suspension unit provided between the axle box and an upper part of the axle box carrier. The vertical suspension unit is preferably independent from the longitudinal hydro-mechanical converters, in order to control the stiffness and deflection in the vertical direction independently from the longitudinal direction. According to one embodiment, the vertical suspension unit comprises a chevron spring having a V-shaped cross-section in a vertical transversal plane parallel to the revolution axis. The vertical suspension unit also provides stiffness in the transverse direction, i.e. the direction parallel to the revolution axis of the axle box. Alternatively the vertical suspension unit comprises a sandwich spring having a set of planar elastomeric elements extending in a horizontal plane. In order to take advantage of the room available below the axle box, the vertical suspension unit may be provided with an elastomeric pad between the axle box and a lower part of the axle box carrier.

[0015] If the deflection of the axle box in the vertical and/or transverse direction is significant, e.g. because the vertical suspension unit has a low stiffness, it may be advisable to release the hydro-mechanical converters from the corresponding displacements. To this end, each of the front and rear longitudinal hydro-mechanical converters further comprises a decoupling spring with a longitudinal stiffness at least ten times, preferably at least twenty times, preferably fifty times greater than a longitudinal stiffness of the elastomeric body, a lateral stiffness less than a two times the lateral stiffness of the elastomeric body, preferably less than the lateral stiffness of the elastomeric body and a vertical stiffness less than two times the vertical stiffness of the elastomeric body, preferably less than the vertical stiffness of the elastomeric body.

[0016] According to one embodiment the axle box carrier forms a ring around the axle box.

[0017] According to one embodiment a vertical suspension assembly connects the axle box carrier to a running gear frame. The vertical suspension units between the axle box carrier and the running gear frame will allow deflection of substantial magnitude in the vertical direction, without negatively impacting the longitudinal hydro-mechanical converters. If vertical suspension units are provided both between the axle box and the axle box carrier and between the axle box carrier and the running gear frame, the latter will preferably have a lower stiffness than the former, preferably more than 1,5 times lower.

[0018] According to an alternative embodiment the axle box carrier is a constituent portion of a running gear frame of a running gear. This will be possible in particular with a flexible running gear frame.

[0019] According to one embodiment a hydraulic reservoir is hydraulically connected to the hydraulic chamber, preferably with a check valve allowing a flow of fluid only from the hydraulic reservoir to the hydraulic chamber, preferably with a volume at least twice the volume of the hydraulic chamber. The hydraulic reservoir provides a temperature compensation volume and delivers

additional hydraulic fluid to offset losses in the hydraulic circuit and maintain the function of the system for an extra period of time in case of leakage. The reservoir may advantageously be provided with a leakage indicator. The hydraulic reservoir may be connected to the hydraulic chamber via an appropriate valve arrangement, in particular a check valve, to ensure a fail-safe operation.

[0020] According to another aspect of the invention, there is provided A running gear for a rail vehicle, comprising at least a pair of wheel axle guiding assemblies as described above, a first hydraulic circuit for establishing a hydraulic connection between a first variable volume hydraulic chamber and a second variable volume hydraulic chamber, and a second hydraulic circuit for establishing a hydraulic connection between a third variable volume hydraulic chamber and a fourth variable volume hydraulic chamber, the first, second, third and fourth variable volume hydraulic chambers being all different chambers and each of the first, second, third and fourth variable volume hydraulic chambers being the variable volume hydraulic chamber of one of the front and rear longitudinal hydro-mechanical converters of one of the wheel axle guiding assemblies of the pair of wheel axle guiding assemblies. Preferably, the first and/or the second hydraulic circuit further comprise a hydraulic reservoir. The hydraulic connection between variable volume hydraulic chambers is effective to allow a circulation of fluid and a balance of pressures when the wheel sets are subjected to quasistatic load.

[0021] One option is to connect the variable volume chamber of the front longitudinal hydro-mechanical converter of each wheel axle guiding assembly with the variable volume chamber of the rear longitudinal hydro-mechanical converter of the same wheel axle guiding assembly.

[0022] Preferred alternative embodiments, however, dispense with any hydraulic connection between the chamber of the front longitudinal hydro-mechanical converter and the chamber of the rear longitudinal hydro-mechanical converter of the same wheel axle guiding assembly.

[0023] Another option is to connect the variable volume chamber of the front longitudinal hydro-mechanical converter of one wheel axle guiding assembly on each lateral side of the running gear with the variable volume chamber of the rear longitudinal hydro-mechanical converter of the other wheel axle guiding assembly on the same lateral side of the running gear and to connect the variable volume chamber of the rear longitudinal hydro-mechanical converter of said one wheel axle guiding assembly on each lateral side of the running gear with the variable volume chamber of the front longitudinal hydro-mechanical converter of said other wheel axle guiding assembly on the same lateral side of the running gear.

[0024] Preferably, the first hydraulic circuit establishes a hydraulic connection between the variable volume hydraulic chamber of the front longitudinal hydro-mechanical converter of one of the wheel axle guiding assemblies

of the pair of the wheel axle guiding assemblies and the variable volume hydraulic chamber of the front longitudinal hydro-mechanical converter of the other of the wheel axle guiding assemblies of the pair of the wheel axle guiding assemblies and second hydraulic circuit establishes a hydraulic connection between the variable volume hydraulic chamber of the rear longitudinal hydro-mechanical converter of one of the wheel axle guiding assemblies of the pair of the wheel axle guiding assemblies and the variable volume hydraulic chamber of the rear longitudinal hydro-mechanical converter of the other of the wheel axle guiding assemblies of the pair of the wheel axle guiding assemblies.

[0025] According to one embodiment, the running gear further comprises at least a front wheel set and a rear wheel set and the such that an end of the front wheel set is supported by the axle box of a front wheel axle guiding assembly of the pair of wheel axle guiding assemblies and that an end of the rear wheel set is supported by the axle box of a rear wheel axle guiding assembly of the pair of wheel axle guiding assemblies. In particular, one option is to connect the variable volume chamber of the front longitudinal hydro-mechanical converter of one wheel axle guiding assembly on each lateral side of the running gear with the variable volume chamber of the front longitudinal hydro-mechanical converter of the other wheel axle guiding assembly on the same lateral side of the running gear and similarly for the variable volume chambers of the rear longitudinal hydro-mechanical converters. This will ensure that the two-wheel sets will rotate in opposite direction about a vertical axis. Another option with similar effect is to connect the variable volume chamber of the front longitudinal hydro-mechanical converter of one wheel axle guiding assembly on each lateral side of the running gear with the variable volume chamber of the rear longitudinal hydro-mechanical converter of the other wheel axle guiding assembly on the other lateral side of the running gear and similarly between the two other variable volume chambers, to form a cross connection.

[0026] According to a most preferred option, however, the running gear comprises at least one wheel set, a left end of the wheel set is supported by the axle box of a left wheel axle guiding assembly of the pair of wheel axle guiding assemblies, and a right end of the wheel set is supported by the axle box of a right wheel axle guiding assembly of the pair of wheel axle guiding assemblies. With this embodiment, the longitudinal translation movement of the wheel set are limited, e.g. when the vehicle accelerates or decelerates, whilst the rotation of the wheel set about a vertical axis is still possible. Moreover, this embodiment provides a fail-safe operating mode in case of leakage.

[0027] Preferably, the running gear does not include any hydraulic connection between the chamber of the front longitudinal hydro-mechanical converter and the chamber of the rear longitudinal hydro-mechanical converter of the same wheel axle guiding assembly.

BRIEF DESCRIPTION OF THE FIGURES

[0028] Other advantages and features of the invention will then become more clearly apparent from the following description of a specific embodiment of the invention given as non-restrictive examples only and represented in the accompanying drawings in which:

- Figure 1 illustrates a longitudinal section of a wheel axle guiding assembly for a running gear of a rail vehicle according to a first embodiment of the invention by a longitudinal vertical plane along section line I-I of Figure 3;
- Figure 2 illustrates a section of the wheel axle guiding assembly of Figure 1 by a horizontal plane along section line II-II of Figure 1;
- Figure 3 is a vertical section of the wheel axle guiding assembly of Figure 1, along section line III-III of Figure 1;
- Figure 4 is a vertical section along section line IV-IV of Figure 1;
- Figure 5 is a longitudinal section of a wheel axle guiding assembly according to a second embodiment of the invention;
- Figure 6 is a longitudinal section of a wheel axle guiding assembly according to a third embodiment of the invention;
- Figure 7 illustrates a section of the wheel axle guiding assembly of Figure 6 by a horizontal plane;
- Figure 8 is a longitudinal section of a wheel axle guiding assembly according to a fourth embodiment of the invention;
- Figure 9 is a longitudinal section of a wheel axle guiding assembly according to a fifth embodiment of the invention;
- Figure 10 is a longitudinal section of a wheel axle guiding assembly according to a sixth embodiment of the invention;
- Figure 11 is a schematic view of a first embodiment of a running gear provided with sets of the wheel axle guiding assemblies according to any one of the previous embodiments of the invention;
- Figure 12 is a schematic view of a second embodiment of a running gear provided with sets of the wheel axle guiding assemblies according to any one of the previous embodiments of the invention;

- Figure 13 is a schematic view of a third embodiment of a running gear provided with sets of the wheel axle guiding assemblies according to any one of the previous embodiments of the invention;
- Figure 14 is a schematic view of a fourth embodiment of a running gear provided with sets of the wheel axle guiding assemblies according to any one of the previous embodiments of the invention;
- Figure 15 is a schematic view of a fifth embodiment of a running gear provided with sets of the wheel axle guiding assemblies according to any one of the previous embodiments of the invention;
- Figure 16 is a schematic view of running gear of Figure 15, operating in a fail-safe mode of operation.

[0029] Corresponding reference numerals refer to the same or corresponding parts in each of the figures.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0030] A wheel axle guiding assembly **10** for a running gear **12** of a rail vehicle is illustrated in Figures **1** to **4**. This wheel axle guiding assembly **10** comprises an axle box **14** located longitudinally between a front part **16** and a rear part **18** of an axle box carrier **20** formed by a C-shaped end portion of a frame **22** of the running gear **12**. The axle box carrier **20** is supported on the axle box **14** by way of a vertical primary suspension unit **24**, which comprises a chevron spring **26** having a V-shaped cross-section in a vertical transversal plane parallel to a revolution axis **100** defined by the axle box **14**. As is well known in the art, the axle box **14** houses a bearing **28**, usually a roller bearing, for guiding an end portion of a wheel axle **30**.

[0031] A front longitudinal hydro-mechanical converter **32** is fixed to the axle box **14** and to the front part **16** of the axle box carrier **20** and a rear longitudinal hydro-mechanical converter **34** is fixed to the axle box **14** and to the rear part **18** of the axle box carrier **20** to allow a fore-and-aft movement of the axle box **14** relative to the axle box carrier **20** parallel to a longitudinal direction **200**. The longitudinal direction **200** in this context and in the whole application is the horizontal direction perpendicular to the horizontal revolution axis **100** defined by the axle box in a reference position. Each of the front and rear longitudinal hydro-mechanical converters **32**, **34** includes a housing **36** fixed to the axle box **14** or integral with the axle box **14**, a plunger **38** fixed to or integral with the axle box carrier **20** and an annular elastomeric body **40** adhered by vulcanisation or otherwise fixed in a sealed manner to the housing **36** and to the plunger **38** so as to form a single variable volume hydraulic chamber **42** between the housing **36**, the plunger **38** and the elastomeric body **40**. A hydraulic inlet and outlet port **44** (see Figure

2) is provided for connecting the variable volume hydraulic chamber 42 to a hydraulic circuit, as will be discussed later on in connection with Figures 9 to 13.

[0032] In this preferred embodiment, the interface 46 between the annular elastomeric body 40 and the housing 36 and the interface 48 between the annular body 40 and the plunger 38 are cylindrical and coaxial. This ensures that the annular elastomeric body 40 is only subjected to shear stress when the plunger 38 and housing 36 move relative to one another in the longitudinal direction 200. The radial dimension of the annular body 40, i.e. the distance between the two interfaces 46, 48 is preferably greater than its longitudinal dimension.

[0033] This arrangement result in a low stiffness of each longitudinal hydro-mechanical converter 32, 34 in the longitudinal direction 200 while the stiffness is much higher in the radial directions, notably in the vertical and transverse directions. The chevron spring 26 has a stiffness which is higher than the hydro-mechanical converters 32, 34 in the vertical and transverse directions but lower in the longitudinal direction 200. As a result, the vertical primary suspension unit 24 is the main path for vertical loads and shares the transverse load with the hydro-mechanical converters 32, 34, which form the main path for longitudinal loads.

[0034] Due to its geometry, and in particular to their large pumping area, the hydro-mechanical converters 32, 34 have a stiffness, which significantly increases with the frequency of the applied load, as become more apparent from the discussion below.

[0035] When the axial load varies at a very low frequency, the hydraulic fluid moves in and out of the variable volume hydraulic chamber 42 through the hydraulic port 44 in phase with the motion of the plunger 38 relative to the housing 36. The static stiffness C_{static} of the hydro-mechanical converter depends mainly on the geometry of the elastomeric body 40 and decreases when the ratio of the radial dimension to the longitudinal dimension of the elastomeric body 40 increases.

[0036] When the frequency of the longitudinal movement of the axle boxes 14 increases, the motion of the hydraulic fluid in and out of the hydraulic chambers 42 is increasingly out of phase with the relative motion between the plunger 38 and the housing 36. When the frequency is sufficiently high the hydraulic chambers 42 can be almost considered as closed chambers, since the movement of the fluid in and out of the chambers becomes insignificant. The behaviour is dependent on the viscosity of the fluid and the hydraulic circuit connecting the chambers, in particular the length and diameter of the connecting pipes. Relative fore and aft movement between the plunger and the housing is still possible despite the incompressible fluid in the hydraulic chamber thanks to a dynamic swell deformation of the elastomeric body 40. The elastomeric body 40 is therefore characterised by a dynamic swell stiffness C_{swell} which is added to the static stiffness C_{static} at higher frequencies. This dynamic swell stiffness increases approximately linearly

with the effective pumping area A of the hydro-mechanical converter, which is the ratio of the elementary variation of volume ΔV of the chamber to the corresponding elementary longitudinal relative movement Δx between the plunger and the housing:

$$C_{swell} \approx K \cdot A = K \frac{\Delta V}{\Delta x}$$

[0037] In practice, the pumping area A is greater than or equal to the effective area A_e of the plunger, i.e. the area of the geometric projection of the surface of the plunger within the housing on a plane P perpendicular to the longitudinal direction. In other words, the greater the effective area A_e of the plunger, the greater the pumping area A , the dynamic swell stiffness C_{swell} and the ratio R of the dynamic stiffness to the static stiffness of the longitudinal hydro-mechanical converter 32, 34. As a rule of thumb, the effective area A_e of the plunger should preferably be greater than half the area of the cross-section A_ϕ of the wheel axle measured in a plane perpendicular to the rotation axis of the wheel axle passing through a roller bearing of the axle box:

$$A \geq A_e \geq \frac{A_\phi}{2}$$

[0038] Thanks to the geometry of the arrangement of the hydro-mechanical converters on each side of the wheel axle, the effective pumping area A can be large, and the dynamic stiffness, will also be very large. Concurrently, the static stiffness can be kept low, which leads to a high ratio of the dynamic stiffness to the static stiffness, preferably of more than 10, preferably of more than 20, and preferably more than 50.

[0039] Due to this high ratio of the dynamic stiffness to the static stiffness, the wheel axle guiding assembly provides a smooth response to the various longitudinal loads at low frequency and a stiffer response at higher frequency, which is particularly advantageous. The wheel axle guiding assembly will respond with a very low stiffness C_{static} to quasistatic longitudinal loads so that the wheel axle 30 will naturally rotate about a vertical axis and find their position in a curve. The stroke of the longitudinal hydro-mechanical converters 32, 34 is greater than with conventional elastomeric or hydro-elastic bushings, which ensures a sufficient deflection of the wheel axle 30 in curves. In response to high frequency longitudinal vibrations, on the other hand, the system will provide a high dynamic stiffness that includes the component C_{swell} so as to efficiently counteract hunting oscillations and provide an excellent stability.

[0040] The cutoff frequency in the frequency response of the system depends not only on the characteristic of the hydro-mechanical converters 32, 34 but also on the characteristics of the hydraulic circuit. Preferably, the cut-

off frequency should be less than 4Hz, ideally between 0,5Hz and 1,5Hz.

[0041] A wheel axle guiding assembly **10** for a running gear **12** of a rail vehicle according to a second embodiment of the invention is illustrated in Figure 5. This wheel axle guiding assembly **10** comprises an axle box **14** located longitudinally between a front part **16** and a rear part **18** of a ring-shaped axle box carrier **20** formed by a C-shaped end portion of a frame **22** of the running gear and a C-shaped lower bracket **120**. The axle box carrier **20** is supported on the axle box **14** by way of a vertical primary suspension unit **24**, which comprises a sandwich spring **126** having a set of planar elastomeric elements extending in a horizontal plane.

[0042] A front longitudinal hydro-mechanical converter **32** is fixed to the axle box **14** and to the front part **16** of the axle box carrier **20** and a rear longitudinal hydro-mechanical converter **34** fixed to the axle box **14** and to the rear part **18** of the axle box carrier **20** to allow a fore-and-aft movement of the axle box **14** relative to the axle box carrier **20** parallel to the longitudinal direction **200** of the running gear **12**. Each of the front and rear longitudinal hydro-mechanical converters **32, 34** includes a housing **36** fixed to or integral with the axle box **14**, a plunger **38** fixed to or integral with the axle box carrier **20** and an annular elastomeric body **40** adhered by vulcanisation or otherwise fixed in a sealed manner to the housing **36** and to the plunger **38** so as to form a single variable volume hydraulic chamber **42** between the housing **36**, the plunger **38** and the elastomeric body **40**. In this embodiment, the interface between the annular elastomeric body and the plunger is frustum-shaped and coaxial with the interface between the annular body and the housing.

[0043] This arrangement results in a low stiffness of each longitudinal hydro-mechanical converter **32, 34** in the longitudinal direction while the stiffness is much higher in the radial directions, notably in the vertical and transverse directions. The sandwich spring **126** has a static stiffness, which is higher than the hydro-mechanical converters **32, 34** in the vertical directions but lower in the longitudinal and transverse directions. As a result, the sandwich spring **126** is the main path for vertical loads while the hydro-mechanical converters **32, 34** form the main path for longitudinal and transverse loads. The response of the wheel axle guiding assembly **10** of Figure 5 to static and dynamic longitudinal loads is essentially similar to that of the first embodiment.

[0044] A wheel axle guiding assembly **10** for a running gear **12** of a rail vehicle according to a third embodiment of the invention is illustrated in Figures 6 and 7. This wheel axle guiding assembly **10** comprises an axle box **14** located longitudinally between a front part **16** and a rear part **18** of an axle box carrier **20** formed by a ring-shaped frame element fixed to the frame **22** of the running gear **12**. The axle box carrier **20** is supported on the axle box **14** by way of a vertical primary suspension unit **24**, which comprises an upper elastomeric pad **226** and a lower elastomeric pad **227**. A front longitudinal hydro-

mechanical converter **32** is provided between the axle box **14** and the front part **16** of the axle box carrier **20** and a rear longitudinal hydro-mechanical converter **34** is provided between the axle box **14** and the rear part **18** of the axle box carrier **20** to allow a fore-and-aft movement of the axle box **14** relative to the axle box carrier **20** parallel to the longitudinal direction **200** of the running gear **12**. Each of the front and rear longitudinal hydro-mechanical converters **32, 34** includes a housing **36** fixed to the axle box carrier **20** or integral with the axle box carrier **20**, a plunger **38** integral with the axle box **14** and an annular elastomeric body **40** adhered by vulcanisation or otherwise fixed in a sealed manner to the housing **36** and to the plunger **38** so as to form a single variable volume hydraulic chamber **42** between the housing **36**, the plunger **38** and the elastomeric body **40**. In this embodiment, the interface **46, 48** between the annular elastomeric body **40** and the housing **36** and between the annular body **40** and the plunger **38** are tapered. An elastomeric buffer **338** forms an abutment between the plunger **38** and the housing **36** for limiting a contraction movement of the hydro-mechanical converter **32, 34**. The response of the wheel axle guiding assembly of Figure 6 and 7 to static and dynamic longitudinal loads is essentially similar to that of the previous embodiments.

[0045] The axle guiding assemblies of the various embodiments of Figures 1 to 7 are particularly adapted to a running gear with a flexible running gear frame that will undergo deformation to respond to vertical load. The embodiment of Figure 8 is more adapted to a rigid running gear frame, which remains substantially without deformation under the usual operative conditions. The axle guiding assembly **10** of Figure 8 differs from the axle guiding assembly of Figures 6 and 7 essentially in that the ring-shaped axle box carrier **20** is not rigidly fixed to the running gear frame **22**. Instead, the running gear frame **22** bears on a pair of vertical primary suspension units **426**, which consist in rubber springs that allow a substantial relative vertical movement between the running gear frame **22** and the axle box carrier **20** and transmit the longitudinal and lateral loads without substantial deformations. The upper and lower elastomeric pads **226, 227** between the axle box carrier **20** and the axle box **14** can be kept very stiff to substantially reduce the relative vertical and transverse motion between the axle box carrier **20** and the axle box **14** and limit the deformation of the elastomeric body **40** of each of the front and rear hydro-mechanical converters **32, 34** in directions perpendicular to the longitudinal direction **200**. The response of the wheel axle guiding assembly **10** of Figure 8 to static and dynamic longitudinal loads is essentially similar to that of the previous embodiments.

[0046] The axle box guiding assembly of Figure 9 derives from the embodiment of Figures 1 to 4 and differs from that embodiment in that an additional spring **526** is interposed between the axle box **14** and each of the longitudinal hydro-mechanical converter **32, 34**. This additional decoupling spring **526** has vertical stiffness less

than two times the vertical stiffness of the hydro-mechanical converter **32**, **34**, a longitudinal stiffness at least ten times greater than the longitudinal stiffness of the hydro-mechanical converter **32**, **34** and a lateral stiffness less than two times than the lateral stiffness of the hydro-mechanical converter **32**, **34**. The decoupling spring **526** can be an elastomer ring around a fixed volume hydraulic chamber **527** filled with hydraulic fluid.

[0047] The axle box guiding assembly of Figure **10** derives from the embodiment of Figures **9** and differs from that embodiment merely in that no fixed volume hydraulic chamber is provided.

[0048] A running gear **12** including two pairs of wheel axle guiding assemblies according to the invention is illustrated in Figure **10**. In Figure **10**, the vertical primary suspension units have been left out for simplicity. The running gear **12** of Figure **11** is a bogie with a two-wheel sets **50**, each comprising left and right wheels **51** at opposite ends **52** of a wheel axle **30**. Each end **52** of each wheel axle **30** is guided for rotation in an axle box **14** of a wheel axle guiding assembly **10**. The two wheel axle guiding assemblies **10** on the same left or right side of the running gear **12** are hydraulically connected with one another via four independent hydraulic circuits **54**, **56**. More specifically, the variable volume hydraulic chamber **42** of the front hydro-mechanic converters **32** of the front and rear wheel axle guiding assemblies **10** on the left side are connected with one another via a hydraulic circuit **54** and the variable volume hydraulic chamber **42** of the rear hydro-mechanic converters **34** of the front and rear wheel axle guiding assemblies **10** on the left side are connected with one another via a hydraulic circuit **56**. Similar hydraulic connections are provided between the axle guiding assemblies **10** on the right side of the running gear **10**. A hydraulic reservoir **58** is connected via a check valve **60** to each of the hydraulic circuits to provide a temperature and leakage compensation. Preferably, each hydraulic reservoir **58**, or more generally each hydraulic circuit **52**, **54**, is provided with a leakage detector **63**. This type of hydraulic link between the front and rear axle will result in passive steering of the front and rear axles **30** in opposite directions.

[0049] An alternative connection between the individual variable volume hydraulic chambers **42** is shown in Figure **12**. The variable volume hydraulic chamber **42** of the front hydro-mechanic converters **32** of the front wheel axle guiding assembly **10** on each side is connected with the variable volume hydraulic chamber **42** of the rear hydro-mechanic converters **34** of the rear wheel axle guiding assembly **10** on the same side of the running gear **12** via a hydraulic circuit **64**, while the variable volume hydraulic chamber **42** of the rear hydro-mechanic converters **34** of the front wheel axle guiding assembly **10** on each side is connected with the variable volume hydraulic chamber **42** of the front hydro-mechanic converters **32** of the rear wheel axle guiding assembly **10** on the same side of the running gear via a hydraulic circuit **66**. This type of hydraulic link between the front and rear

axle will result in passive steering of the front and rear axles in the same direction.

[0050] An alternative connection between the individual variable volume hydraulic chambers **42** is shown in Figure **13**. The variable volume hydraulic chamber **42** of the front hydro-mechanic converters **32** of the front wheel axle guiding assembly **10** on each side is connected with the variable volume hydraulic chamber **42** of the rear hydro-mechanic converters **34** of the rear wheel axle guiding assembly **10** on the other side of the running gear **12** via a hydraulic circuit **154**, while the variable volume hydraulic chamber **42** of the rear hydro-mechanic converters **34** of the front wheel axle guiding assembly **10** on each side is connected with the variable volume hydraulic chamber **42** of the front hydro-mechanic converters **32** of the rear wheel axle guiding assembly **10** on the other side of the running gear via a hydraulic circuit **156**. This type of hydraulic link between the front and rear axle will result in passive steering of the front and rear axles in opposite directions.

[0051] It may be appropriate to provide the running gear with additional distribution valves so as to switch configurations between two types of hydraulic circuits depending on the revolution speed of one of the wheel axles, e.g. with the configuration of Figure **11** or Figure **13** at low speed and the configuration of Figure **12** at higher speed.

[0052] A wheel set **50** provided with two wheel axle guiding assemblies **10** according to the invention for guiding the two opposite ends **52** of a wheel axle **30** is illustrated in Figure **14**. Two independent hydraulic circuits **68**, **70** are formed, each to connect the variable volume hydraulic chamber **42** of the front hydro-mechanic converters **32** of one wheel axle guiding assembly **10** with the variable volume hydraulic chamber **42** of the rear hydro-mechanic converters **34** of the same wheel axle guiding assembly **10**. A hydraulic reservoir **58** is provided in each of the hydraulic circuits **68**, **70**. This embodiment can be implemented in a one-axle running gear or in a two-axle bogie.

[0053] An alternative connection between the individual variable volume hydraulic chambers **42** is shown in Figure **15**. Two independent hydraulic circuits **72**, **74** are formed, one to connect the variable volume hydraulic chambers **42** of the front hydro-mechanic converters **32** of the left and right wheel axle guiding assemblies **10** with one another and another one to connect the variable volume hydraulic chamber **42** of the rear hydro-mechanic converters **32** of the left and right wheel axle guiding assemblies. A hydraulic reservoir **58** is provided in each of the hydraulic circuits **72**, **74**. This embodiment can be implemented in a one-axle running gear or in a two-axle bogie. This embodiment is particularly advantageous as it combines a very low static stiffness for rotation about the vertical axis with a limitation of translation movement of the axle parallel to the longitudinal axis. This is particularly helpful to preserve the steerability when the vehicle brakes or accelerates, the longitudinal forces being trans-

mitted with minimal longitudinal translation of the axle.

[0054] Moreover, this embodiment provides a fail-safe operating mode illustrated in Figure 16. If one of the hydraulic circuits leaks (in Figure 16, the hydraulic circuit 72) and there is not enough hydraulic fluid left in that circuit, the reservoir 58 of the other hydraulic circuit will provide additional fluid in that circuit to force the wheel axle 30 towards the abutment position illustrated in Figure 16. In this position, the wheel set 50 will not be able to rotate about the vertical axis, but will remain in a stable position. To this end, each reservoir 58 should preferably have a capacity superior to the volume of the respective hydraulic circuit, i.e. in practice at least twice and preferably more than twice the volume of the hydraulic chambers 42.

[0055] While the above examples illustrate preferred embodiments of the present invention it is noted that various other arrangements can also be considered, in particular combinations of features from different embodiments.

Claims

1. A wheel axle guiding assembly (10) comprising:

- an axle box (14) defining a horizontal revolution axis (100) and a longitudinal horizontal direction (200) perpendicular to the revolution axis (100);
- an axle box carrier (20), the axle box (14) being located longitudinally between a front part (16) and a rear part (18) of the axle box carrier (20); and
- a front longitudinal hydro-mechanical converter (32) fixed to the axle box (14) and the front part (14) of the axle box carrier (20) and a rear longitudinal hydro-mechanical converter (34) fixed to the axle box (14) and the rear part (18) of the axle box carrier (20) to allow a fore-and-aft movement of the axle box (14) relative to the axle box carrier (20) parallel to the longitudinal direction (200);

characterised in that each of the front and rear longitudinal hydro-mechanical converters (32, 34) includes a housing (36), a plunger (38) and an elastomeric body (40) fixed to the housing (36) and to the plunger (38) so as to allow a fore-and-aft relative movement parallel to the longitudinal direction (200) between the plunger (38) and the housing (36), a single variable volume hydraulic chamber (42) being formed between the housing (36), the plunger (38) and the elastomeric body (40), each of the front and rear longitudinal hydro-mechanical converters (32, 34) further including a hydraulic port (44) for connecting the variable volume hydraulic chamber (42) to an external hydraulic circuit (54, 56, 64, 66, 68, 70, 72, 74).

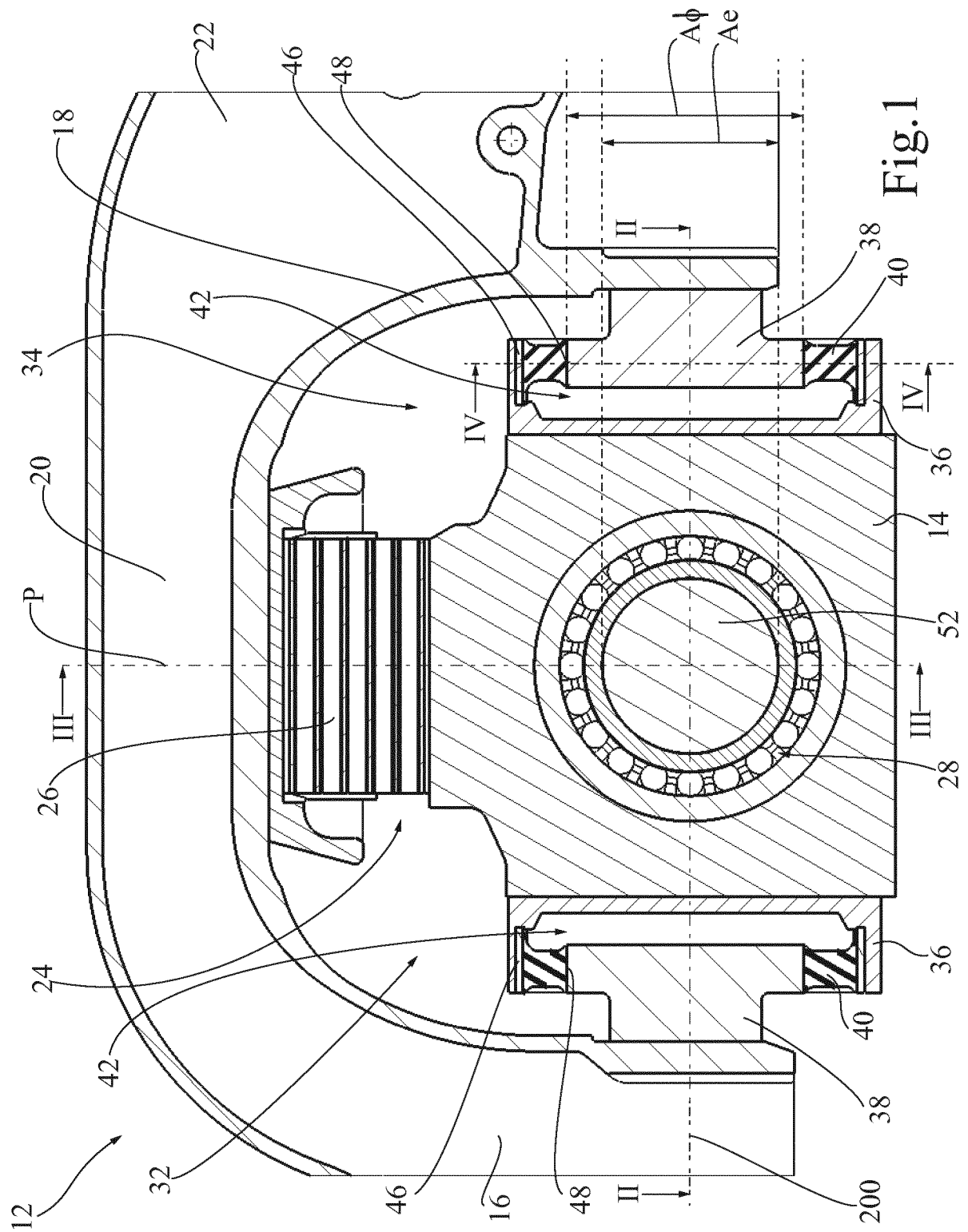
2. The wheel axle guiding assembly of claim 1, wherein the axle box (14) houses a bearing (28) having an inner diameter defining a cross-sectional area A_{ϕ} of an end (52) of a wheel axle (30) to be received in the bearing (28) and the plunger has an effective area A_e measured in a plane perpendicular to the longitudinal direction (200), which is greater than half the cross-sectional area A_{ϕ} , preferably greater than the cross-sectional area A_{ϕ} .
3. The wheel axle guiding assembly of any one of the preceding claims, wherein each of the front and rear longitudinal hydro-mechanical converters (32, 34) has a longitudinal stiffness, which increases with a frequency of the fore-and-aft movement of the axle box (14) relative to the axle box carrier (20) from a quasistatic stiffness value to a dynamic stiffness value, wherein the plunger (38) and the elastomeric body (40) have dimensions such that a ratio R of the dynamic stiffness value to the quasistatic stiffness value is greater than 10, preferably greater than 20, preferably greater than 50.
4. The wheel axle guiding assembly of any one of the preceding claims, further comprising a vertical suspension unit (24) provided between the axle box (14) and an upper part of the axle box carrier (20).
5. The wheel axle guiding assembly of any one of the preceding claims, wherein each of the front and rear longitudinal hydro-mechanical converters (32, 34) further comprises a decoupling spring (526) with a longitudinal stiffness at least ten times, preferably at least twenty times, preferably fifty times greater than a longitudinal stiffness of the elastomeric body (40), a lateral stiffness less than a two times the lateral stiffness of the elastomeric body (40), preferably less than the lateral stiffness of the elastomeric body (40) and a vertical stiffness less than two times the vertical stiffness of the elastomeric body (40), preferably less than the vertical stiffness of the elastomeric body (40).
6. The wheel axle guiding assembly of any one of the preceding claims, wherein the axle box carrier (20) forms a ring around the axle box.
7. The wheel axle guiding assembly of any one of claims 1 to 6, further comprising a vertical suspension assembly (426) for connecting the axle box carrier (20) to a running gear frame (22).
8. The wheel axle guiding assembly of any one of claims 1 to 6, wherein the axle box carrier (20) is a constituent portion of a running gear frame (22) of a running gear (12).
9. The wheel axle guiding assembly of claim 8, wherein

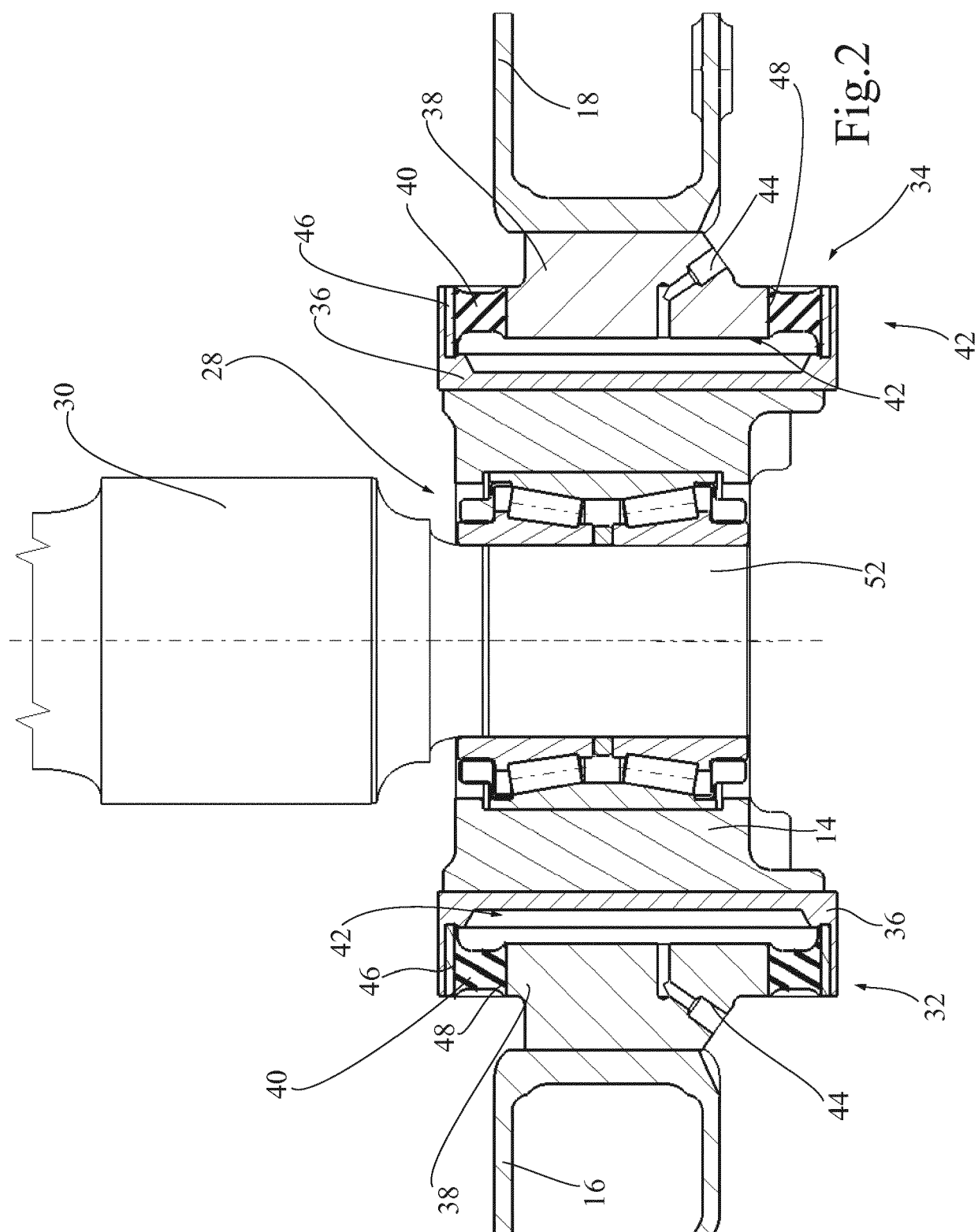
the running gear frame (22) is flexible.

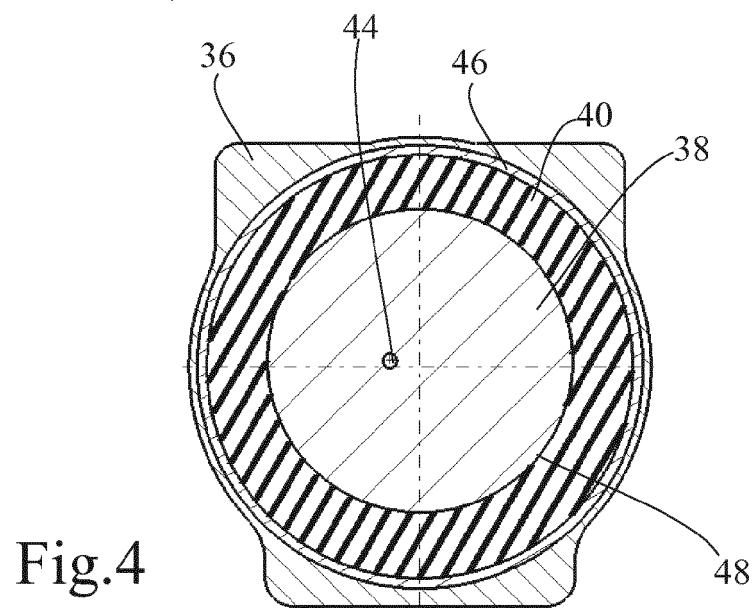
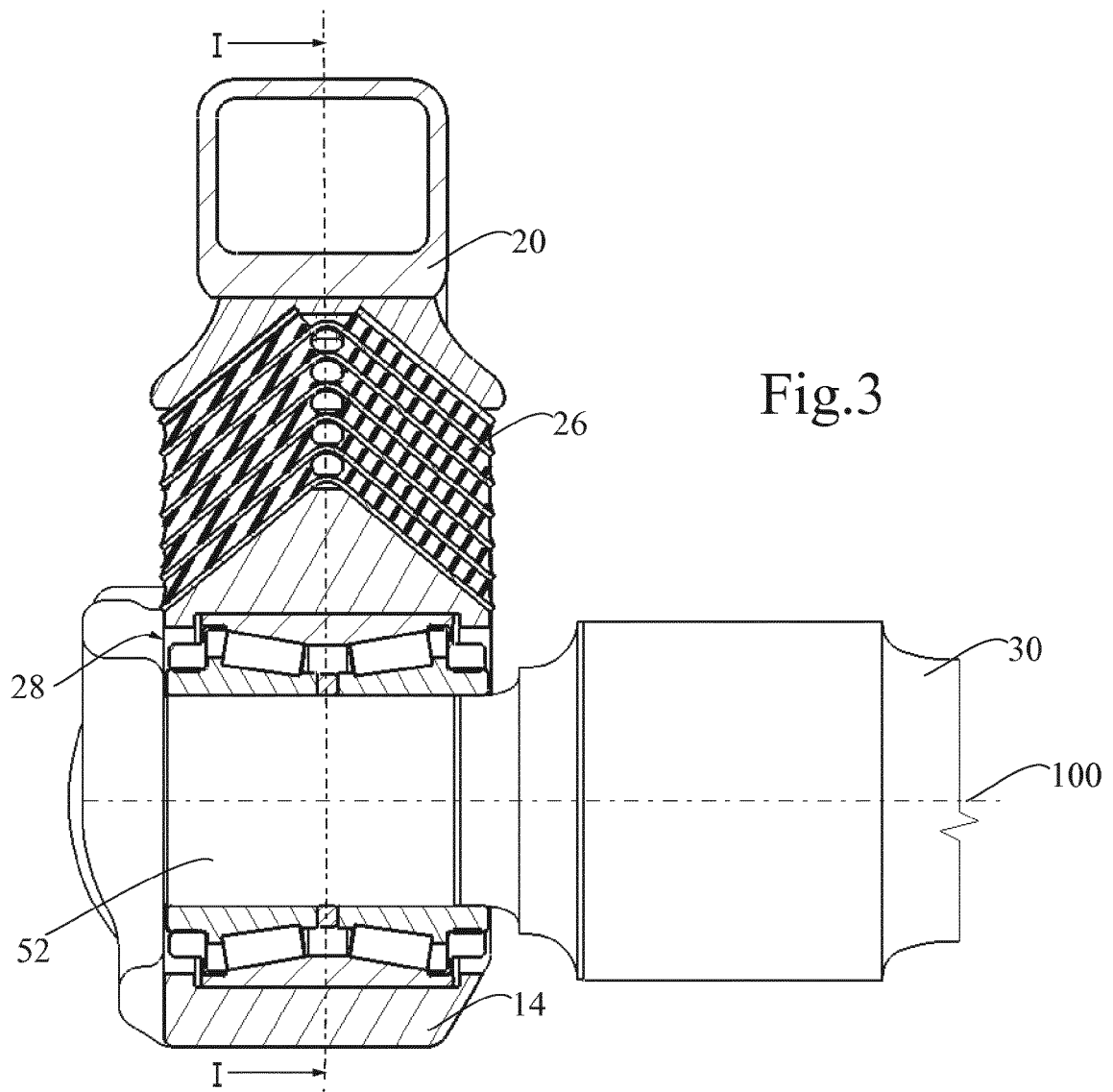
10. The wheel axle guiding assembly of any one of the preceding claims, further comprising a hydraulic reservoir (58) hydraulically connected to the hydraulic chamber (42), preferably with a check valve allowing a flow a fluid only from the hydraulic reservoir (58) to the hydraulic chamber (42), preferably with a volume at least twice the volume of the hydraulic chamber (42). 5
11. A running gear (12) for a rail vehicle, comprising at least a pair of wheel axle guiding assemblies (10) according to any one of the preceding claims, a first hydraulic circuit (54, 64, 68, 72) for establishing a hydraulic connection between a first variable volume hydraulic chamber (42) and a second variable volume hydraulic chamber (42), and a second hydraulic circuit (56, 66, 70, 74) for establishing a hydraulic connection between a third variable volume hydraulic chamber (42) and a fourth variable volume hydraulic chamber (42), the first, second, third and fourth variable volume hydraulic chambers (42) being all different chambers and each of the first, second, third and fourth variable volume hydraulic chambers being the variable volume hydraulic chamber (42) of one of the front and rear longitudinal hydro-mechanical converters (32, 34) of one of the wheel axle guiding assemblies (10) of the pair of wheel axle guiding assemblies (10). 10 15 20 25 30
12. The running gear of claim 11, wherein the first hydraulic circuit (54, 64, 68, 72) establishes a hydraulic connection between the variable volume hydraulic chamber (42) of the front longitudinal hydro-mechanical converter (32) of one of the wheel axle guiding assemblies (10) of the pair of the wheel axle guiding assemblies (10) and the variable volume hydraulic chamber (42) of the front longitudinal hydro-mechanical converter (32) of the other of the wheel axle guiding assemblies (10) of the pair of the wheel axle guiding assemblies (10) and second hydraulic circuit (56, 66, 70, 74) establishes a hydraulic connection between the variable volume hydraulic chamber (42) of the rear longitudinal hydro-mechanical converter (34) of one of the wheel axle guiding assemblies (10) of the pair of the wheel axle guiding assemblies (10) and the variable volume hydraulic chamber (42) of the rear longitudinal hydro-mechanical converter (34) of the other of the wheel axle guiding assemblies (10) of the pair of the wheel axle guiding assemblies (10). 35 40 45 50
13. The running gear of any one of claims 11 to 12, further comprising at least a front wheel set (50) and a rear wheel set (50), wherein an end (52) of the front wheel set (50) is supported by the axle box (14) of a front wheel axle guiding assembly (10) of the pair 55

of wheel axle guiding assemblies (10), and an end (52) of the rear wheel set (50) is supported by the axle box (14) of a rear wheel axle guiding assembly (10) of the pair of wheel axle guiding assemblies (10).

14. The running gear of any one of claims 11 to 12, further comprising at least one wheel set (50), wherein a left end (52) of the wheel set (50) is supported by the axle box (14) of a left wheel axle guiding assembly (10) of the pair of wheel axle guiding assemblies (10), and a right end (52) of the wheel set (50) is supported by the axle box (14) of a right wheel axle guiding assembly (10) of the pair of wheel axle guiding assemblies (10).
15. The running gear of any one of claims 11 to 14, wherein the running gear does not include any hydraulic connection between the chamber (42) of the front longitudinal hydro-mechanical converter (32) and the chamber (42) of the rear longitudinal hydro-mechanical converter (32) of the same wheel axle guiding assembly (10).







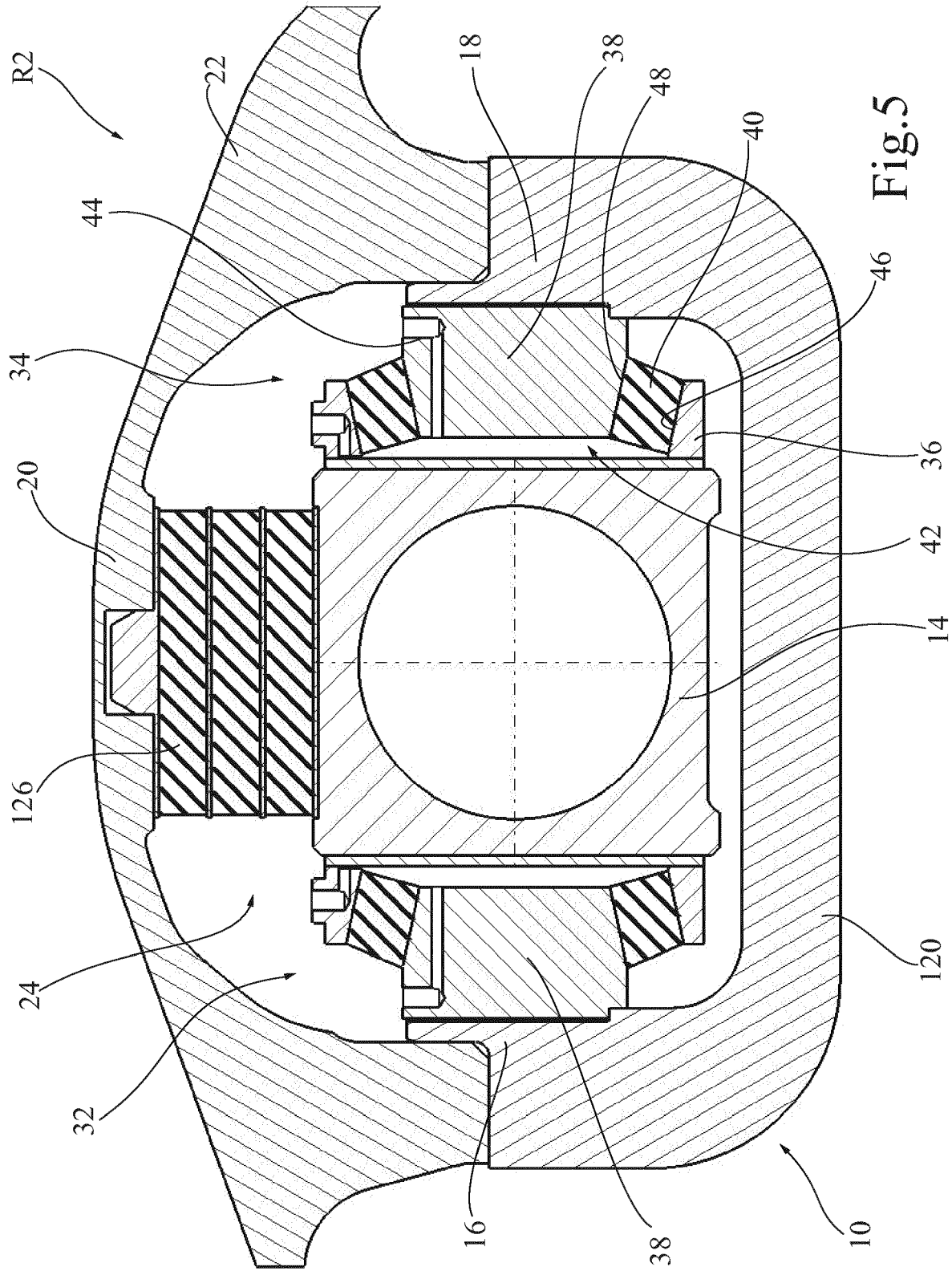


Fig. 5

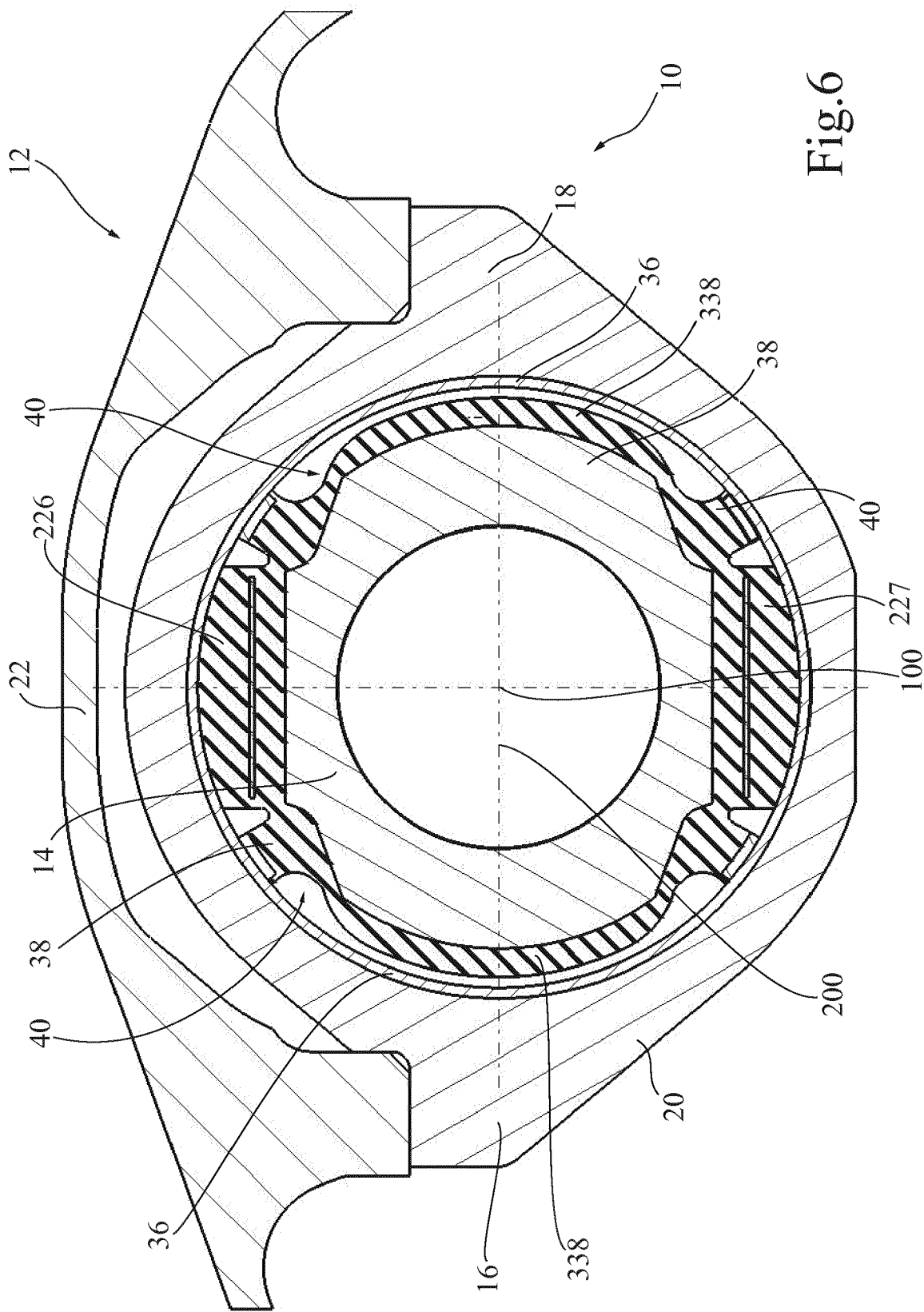


Fig.6

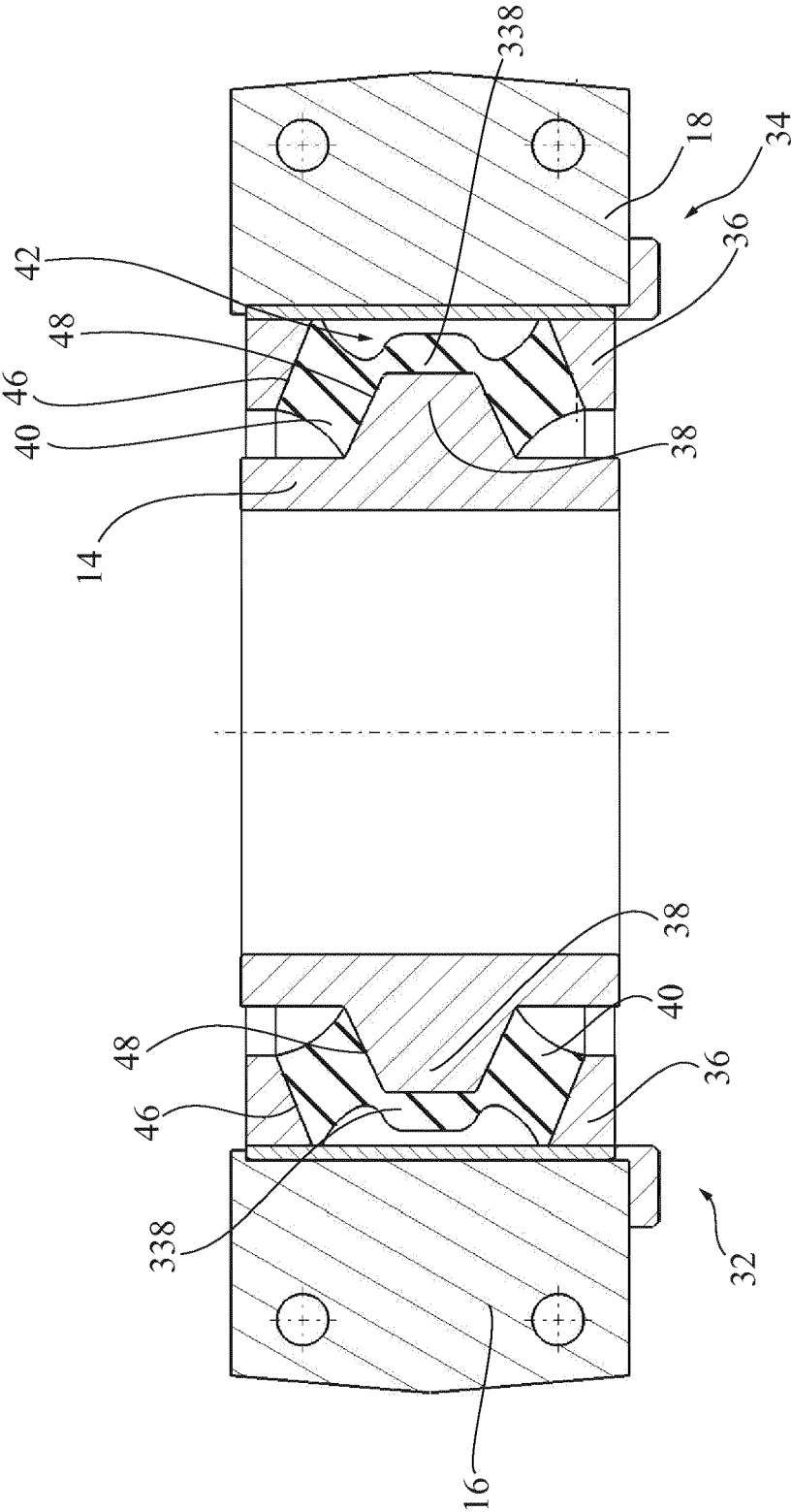
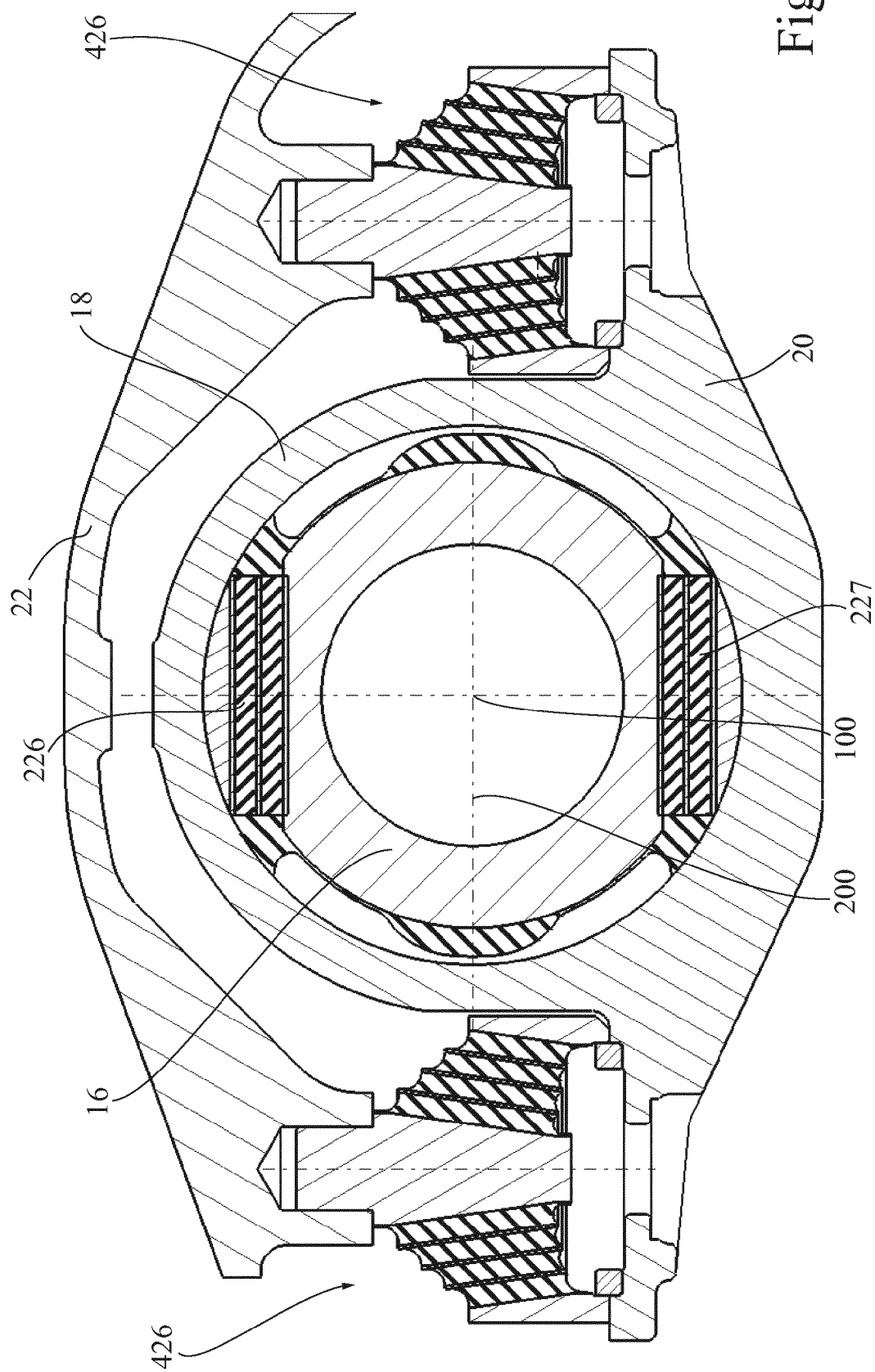


Fig.7



Fi. 8

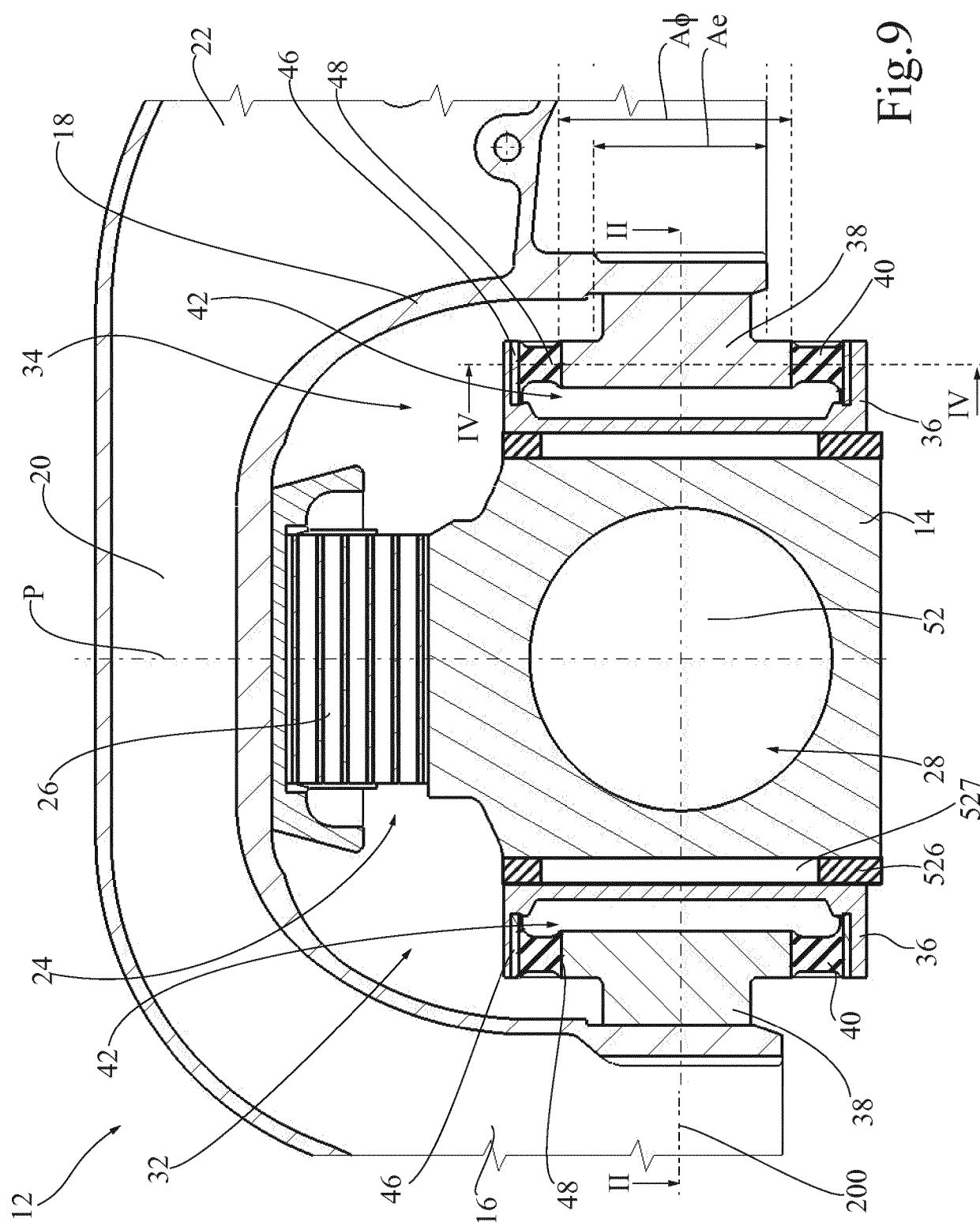


Fig. 9

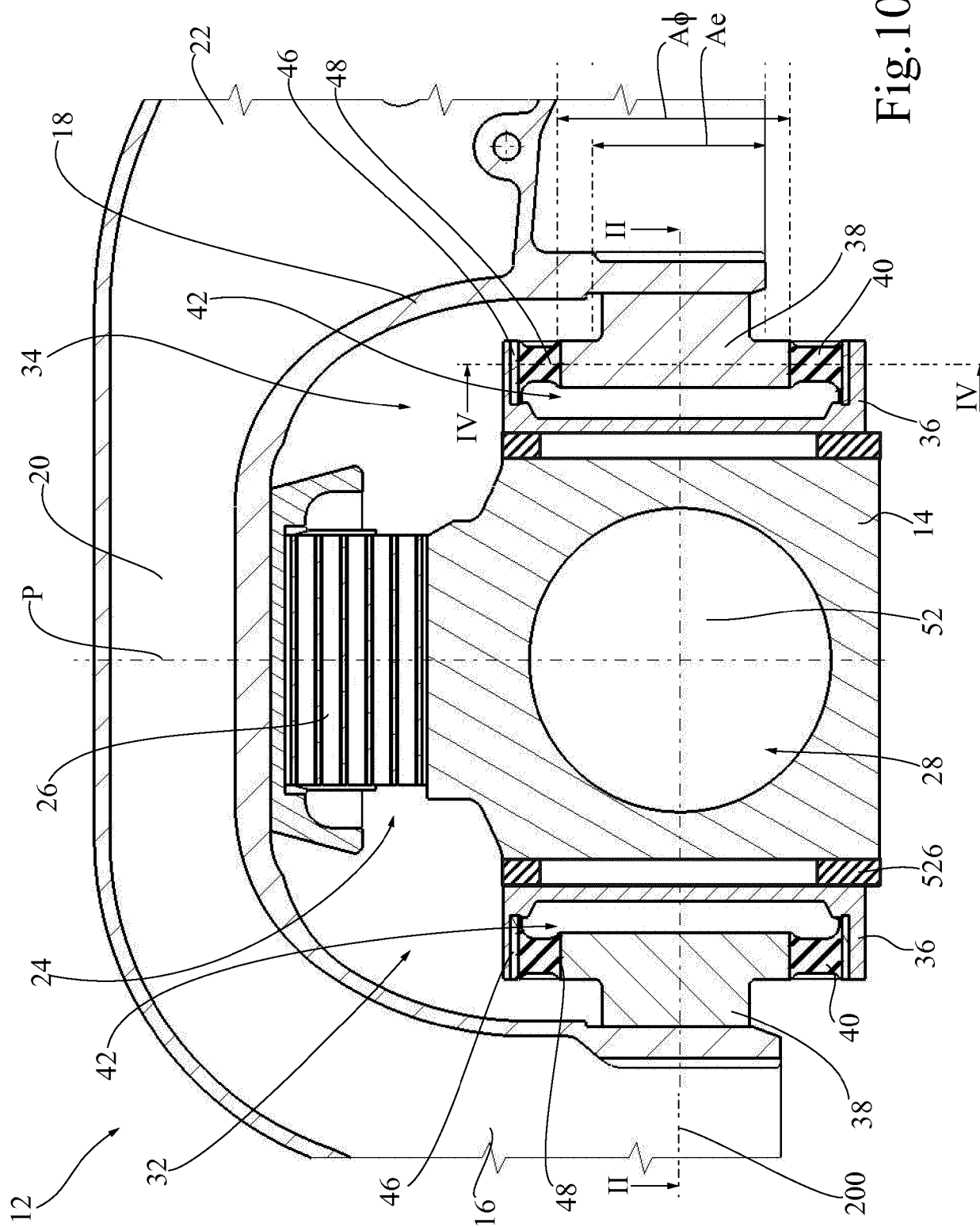


Fig.10

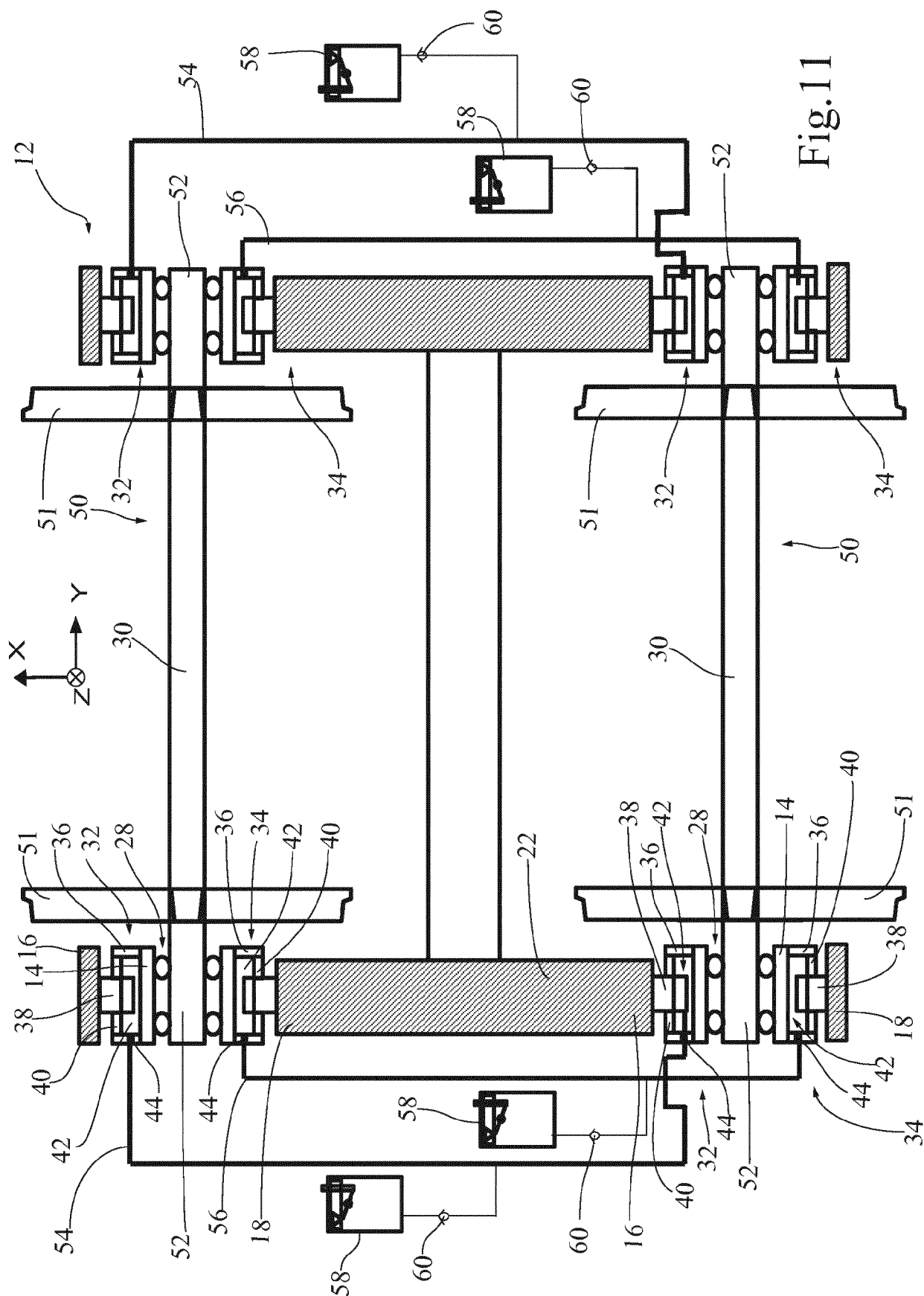


Fig. 11

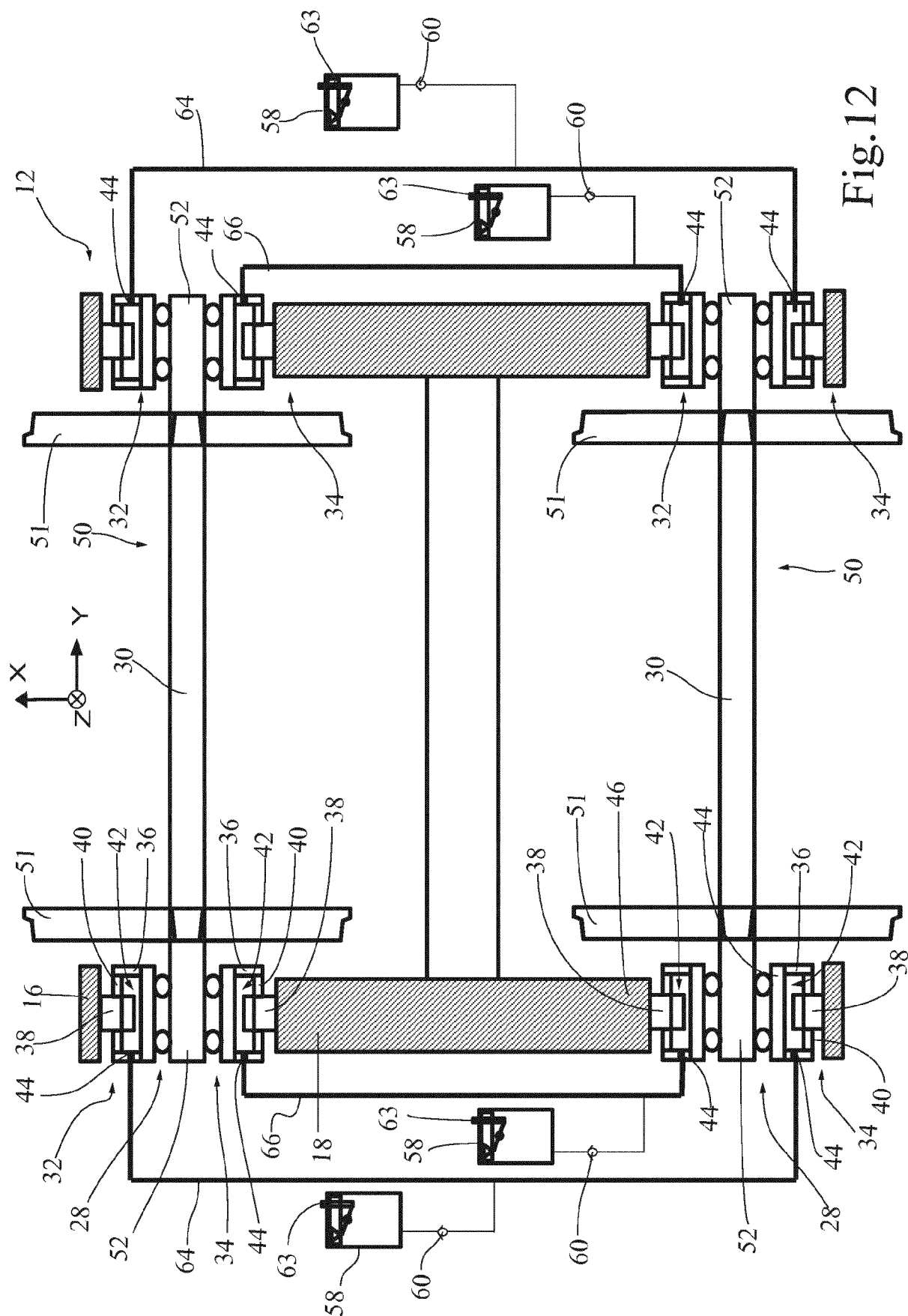
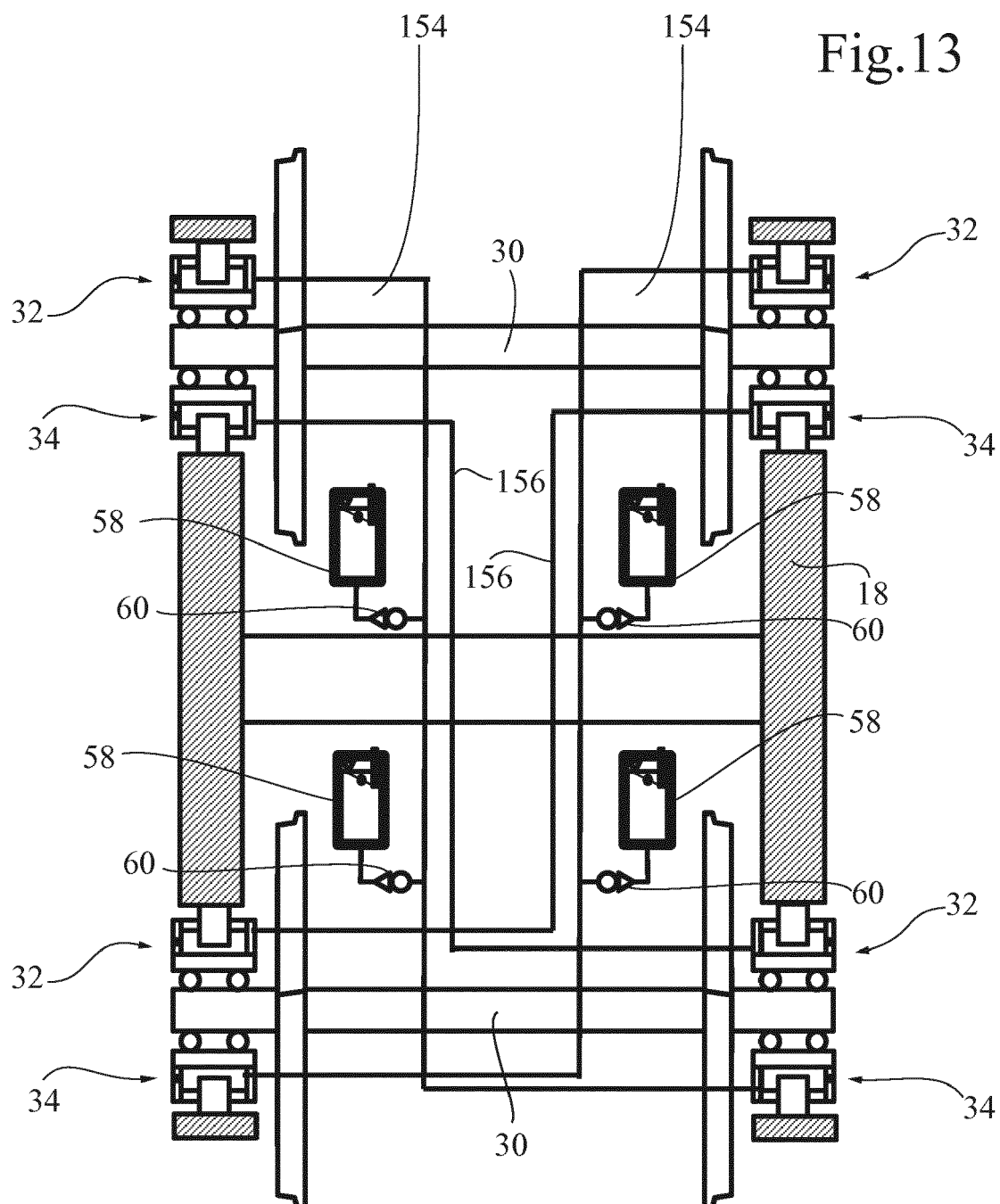


Fig. 12

Fig.13



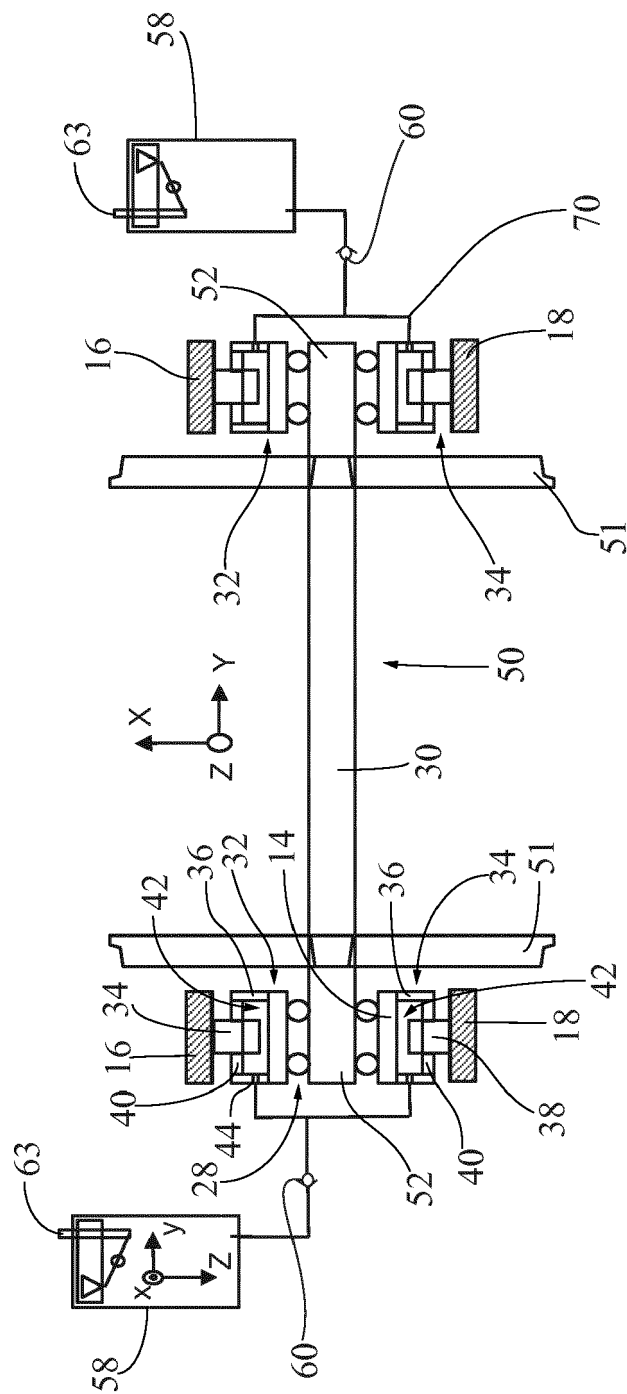
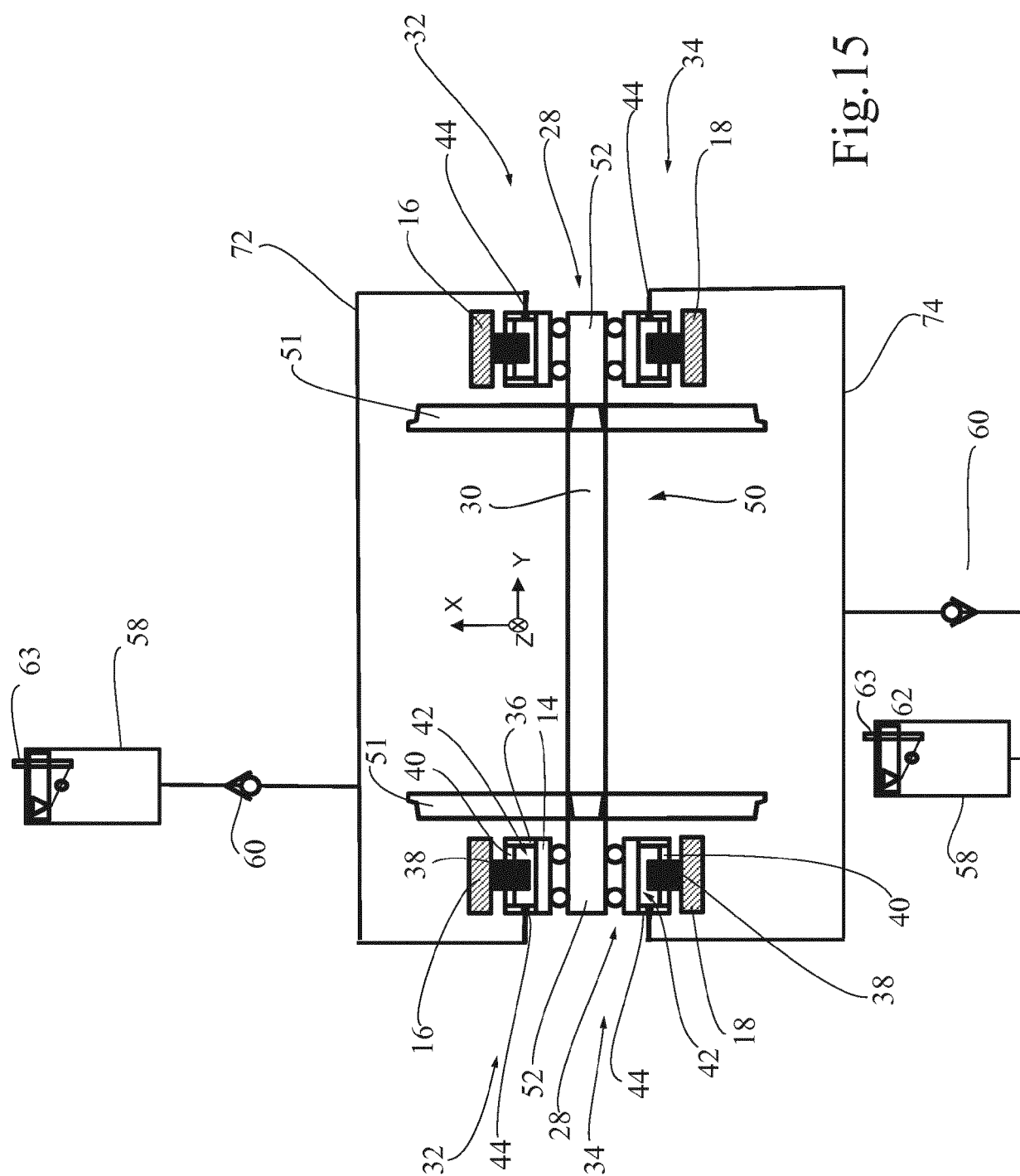


Fig.14



Li. 50.15

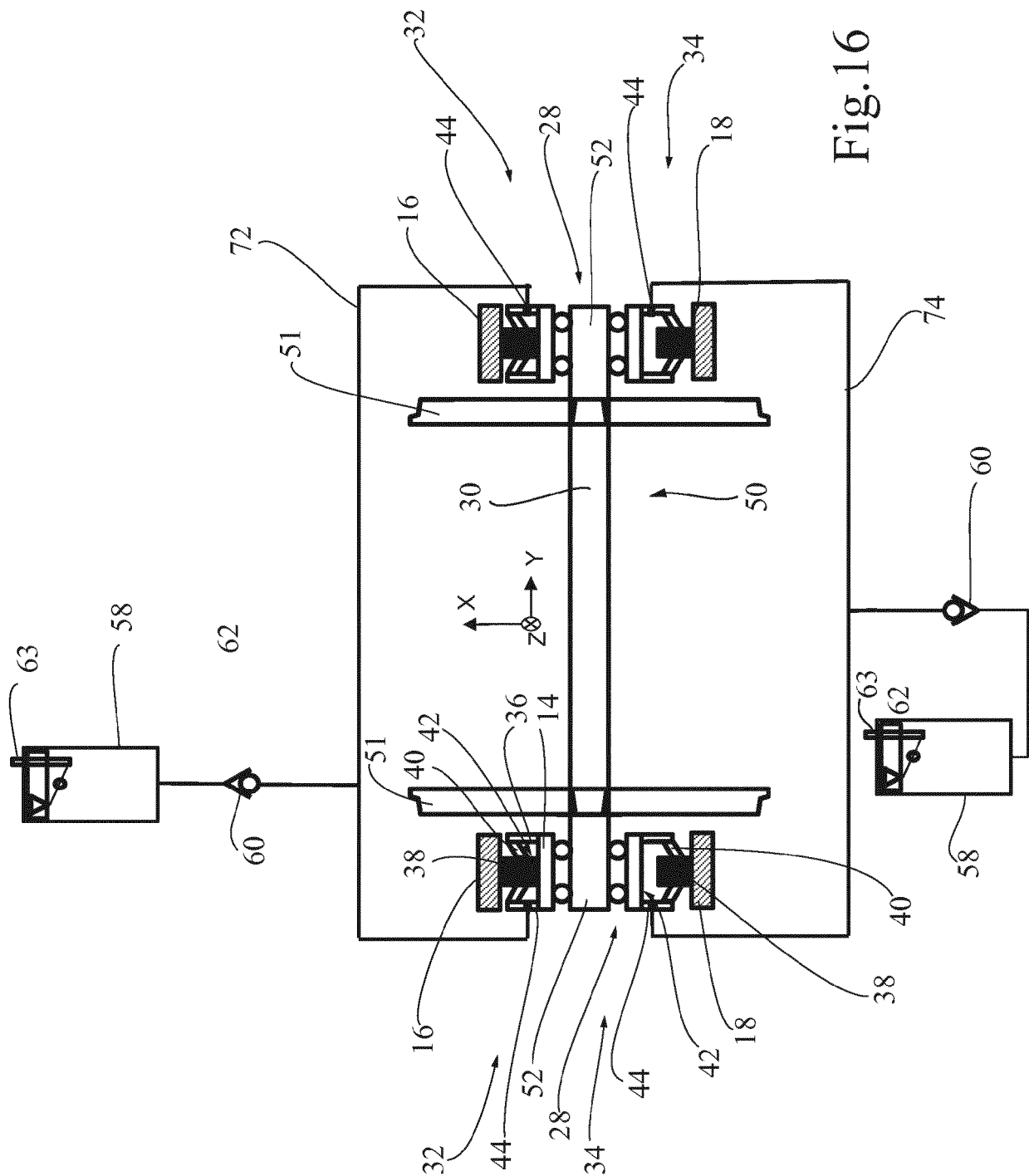


Fig. 16



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Application Number
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 12 August 2016	Examiner Lendfers, Paul
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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