

Title: Rolling Bodies

Field of invention

This invention relates to linear guides and is concerned with the controlled rolling of rolling elements located in a guide, and with a longitudinal guidance system having rolling bodies and a rolling body guide matched thereto.

Background to the invention

Rolling bodies (e.g. roller slide tables) and the associated guides on which they run are used for the low friction performance of movement sequences, for which a specific linear or longitudinal guide system type has been designed. Numerous longitudinal guide systems with rollers, balls and other rolling bodies are known. What is always sought is a very low-friction relative movement between two bodies, e.g. a guide or track and an element movable thereon, i.e. the rolling body. Nowadays such longitudinal guides are a function of the components of conventional ball bearings, whereof numerous different constructions exist. It is common to all of them that the balls are arranged in a row, which are placed in alignment in a ball race or cage. An example is provided by US Patent 2 952 145, in which two rows of balls are so arranged with respect to one another that they roll on one another. The object is to minimize sliding friction, but this only occurs in the indicated construction if the

force pattern through the loading passes precisely through two ball pairs. However, this loading case is critical and cannot be maintained in operation, because the two parts displaceable relative to one another and mounted on balls undergo relative turning and even the slightest rotation means that the apparatus is not operating in an optimum manner. Thus, there is no real operating case leading to the object of the aforementioned published specification because, as stated, this construction cannot absorb a "sloping" force application without a considerable rise in the sliding friction. Thus, despite the symmetry of the solution the optimum force application is limited to a single point for each pair of balls.

Due to the necessary manufacturing precision, these rolling bodies with the always associated race-way are generally expensive, and for most applications specially adapted types or constructions have to be used. However, this means that they can only be used in one field and not for multiple purposes.

Roll guidance systems exist which comprise a guide rail and two associated guide blocks, which are interconnected by means of a web to form a guide carriage (rolling body). When the guide block moves on the rails, the balls revolve in closed ball races via a return channel. Such ball rotation elements are particularly suitable for large displacements and can be operated in any position. However, such circulating ball races are also subject to problems, and in the case of rolling element return guides any feed impacts of said elements must be avoided, which involves a corresponding technical cost. For example, the balls must be pressed with a constant pressure against the guide contact surfaces of the rail. This is also

necessary in order to bring about a stick-slip-free displaceability. In addition, it is generally necessary to use profile-ground raceways. Although these solutions are robust and proven, they are complicated and expensive.

For the lowest possible friction, guide rails exist with single-row flat ball cages and the rolling elements are in two-point contact with the raceways. These linear guides adapt in optimum manner to the loading direction and are not sensitive to angle errors in the transverse direction. They are not suitable for passing round curves. Preference is given to the use of needle rollers, cylinder rollers, etc. with which loose bearings are also possible in flat cage guides.

In general, ball rails for ball guides are used for higher speeds and loadings. Roll rails are suitable for exact adjusting movements. Ball guides are robust and roll guides, particularly cross roll guides are precise (clearance-free).

A problem of the present invention is to provide a longitudinal guidance apparatus having a rolling body guide and a rolling body guidable therein, which has a low overall frictional resistance in such a way that the proportion of the rolling resistance preponderates in all conventional loading cases and the frictional resistance of the rolling body is always kept at a minimum. In addition, the overall longitudinal guidance system must make it possible to use a very high proportion of plastics, without impairing the characteristics required of longitudinal guidance systems. This must lead to a

longitudinal guidance system, which has a slip-stick-free displaceability, minimum frictional resistance, unrestrictedly long displacement paths and this must be the case with low production costs using materials, e.g. plastics which are favourable from the cost and processing standpoint and which also permits a more universal use than is the case with conventional longitudinal guidance systems.

Summary of invention

According to the present invention there is provided a longitudinal guidance apparatus having a rolling body guide and a rolling body guidable therein, in which in the rolling body are arranged rolling elements and support faces for coupling in loading forces, the rolling body guide being a guide channel with rail members for receiving the rolling elements, wherein the rolling body has at least one integrated rolling body cage in which three rolling elements are arranged in recesses the guide channel containing for each rolling element a rail member with rolling element rails which are mutually so arranged that the connecting lines from the bearing point of a rolling element on its rail to a contact point between two rolling elements form an obtuse angle, and at least one support face is provided in each recess in the rolling element cage for each rolling element in such a way that a line perpendicular to this support face is also substantially perpendicular to the connecting line from the bearing point of the rolling element on its rail to the contact or rolling point between two rolling elements.

As stated, a longitudinal guidance system comprises a

rolling body and its rolling body guide. The rolling body comprises parts moved relative to one another, much as in the system consisting of a motor car and a road, in which the car (seen from the engine) comprises a seat housing and rolling wheels. The problem is therefore also to cope with the relative movements within the rolling body.

In the same way as the weight of the seat housing in the car is supported on the axles with the wheels (rolling elements) arranged thereon, the e.g. ball cage of a rolling body must be supportable on the rolling element, in order to bring the force action to the guideway.

The invention is based on the idea that if it is possible to support the ball cage on the balls in such a way that there is a minimum sliding friction, then most of the total frictional resistance will be limited to rolling friction, which is known to be the lowest resistance. It is much easier to technically control rolling friction than sliding friction.

The low-friction coupling together of forces (e.g. a compressive force) by means of two bodies moving relative to one another, i.e. from one body to the other, takes place most advantageously if the relative movement between the bodies is close to or is zero. In the case of rolling bodies this constitutes a problem. Thus, in the case of one rolling ball the circumferential speed is only zero or close thereto at the rotational pole, i.e. the position from which the rolling axis extends, and in the immediate vicinity thereof. However, in the case of a ball, which can be looked upon as an isotropic body, this rolling axis can be anywhere, or more correctly in an infinite number of positions. Therefore the problem also exists of

controlling the rolling elements in such a way that their rolling axes during rolling are located in space, in such a way that the ball cage can be supported in the closer region of the rotational pole, i.e. a rotation invariant zone on a rolling ball, and is also in fact supported there in different loading situations.

As a result of a specific arrangement of the rolling elements in a cage, and during rolling also a relationship to a guide channel with ball rails, on which the rolling elements can roll, there is provided a longitudinal system with the aforementioned advantages. Although the geometrically symmetrical ball shape has the least positionally defined behaviour, the preferred embodiment makes use of balls as rolling elements. In the discussion of the embodiment it will be shown that when using the proposed technical teaching there is a uniform stochastic wear on a spherical rolling element over a longer operating period.

Appropriate text books show that the friction coefficient μ for a pure rolling friction of steel (hard) on steel (hard) is 0.001, and for sliding friction of steel on steel is 0.1 to 0.15. The approximately equally divided up mixed friction thereof between the same hard materials is 0.01 to 0.015, i.e. it is almost precisely halfway between. Constructionally every effort is made to obtain pure rolling friction, which naturally leads to corresponding constraints. A high rolling friction proportion is obtained in a roller or needle bearing and with reservatins also in a ball bearing and in linear guides, in which only a cylindrical rolling element provides the force between the two partners moving

relative to one another. However, it must be borne in mind that the rolling friction can e.g. exceed a system-immanent sliding friction from the resistance standpoint.

A longitudinal guidance system according to the invention makes us of the advantages of a ball as a rolling element, whilst still controlling the other, less desired characteristics. Unlike in the case of conventional longitudinal guidance systems, in the system according to the invention a pretension or prestressing is not required, so that there is also no need to set a bearing clearance. Unrestrictedly long displacement paths can be obtained and forces from all transverse directions and moments about all axes are absorbed in such a way that the basic characteristics is always maintained. No profile-ground raceways are required and also no roller or ball circulation is needed, which occurs where large stroke lengths are needed.

Balls which roll in a cage are supported in the latter during the movement. If this occurs on one part of the cage with a high circumferential speed, sliding friction occurs there and this significantly contributes to the total resistance. Thus, it is advantageous for the cage support acting on the ball arrangement to only come into effect where the circumferential speed of the ball is zero or close to zero, i.e. at the two points on the rolling ball from which extend the rolling axis. These are speed-invariant points or rotation poles which, depending on the rolling of the ball, can be located anywhere on its surface.

Brief description of the drawings

An embodiment of the invention using balls as rolling elements will now be described in detail with reference to the accompanying drawings in which:

Figure 1A is a front view of a rolling body according to the invention inserted in a guide channel;

Figure 1B shows the rolling element cage with two ball triplets in perspective, and in section through a ball triplet as shown in Fig. 1A;

Figure 1C shows the rolling element cage in cross-section in the vicinity of the ball centre of the triplet;

Figure 1D shows in perspective a preferred embodiment of a race profile in a guide channel without rolling element rails;

Figure 2A shows a plurality of aligned rolling bodies

according to Fig. 1A, seen from the side, the guide channel being covered, i.e. only one half being visible, so that in this way a "chain" of rolling bodies can be formed and in turn constitutes a rolling body;

Figure 2B shows a rolling body formed from two sub-rolling bodies, in each case with one ball triplet and a connecting web;

Figure 2C shows a further variant of a plurality of rolling bodies;

Figure 3A represents the kinematics of the rolling body abstracted from the ball;

Figure 3B diagrammatically shows the "balancing" action on the ball triplet in the rolling direction through the rolling friction between two balls rolling on one another and on a race;

Figure 3C diagrammatically shows the preferred pattern of the rolling points between the balls of a triplet and with respect to the race;

Figure 4 shows the division of the forces in the rolling body in the case of loading from above through the centre of the arrangement (comprehensive load);

Figure 5A shows the division of the forces in the rolling body in the case of loading from below through the centre (tensile loading);

Figure 5B shows two rolling elements for a specific operating form, but not in accordance with the present invention;

Figure 6 shows the division of the forces in the rolling body in the case of loading from the side through the centre (side loading);

Figure 7 shows the division of the forces in the rolling body in the case of twisting loading alongside the centre (rotary loading); and

Figure 8 shows an embodiment with a closed, tubular rolling body guide, in which the rolling bodies are combined in the form of a chain.

Detailed description

As shown in Fig. 1A, a rolling body 1 according to the invention is constructed as the basic component in such a way that it is supported in each movement position in itself, i.e. on its three balls. This basic arrangement comprises three balls 3 whose centres, when connected in each case by two ball radii, describe an equilateral triangle. The balls roll one upon the other, which permits an unrestricted stroke without having to follow a ball circulation path. Each ball has four possible contact points for rolling. Each ball can bear at two points on ball rails 6 of a member in the running channel 4 and on two points with one each on a partner ball, so that there are nine instead of twelve possible contact points for three balls. It will be shown hereinafter that in different loading cases three to six of these contacting points are simultaneously used for supporting

and rolling purposes. On the ball rail 6 of the members in the channel 4 the bearing points have the same spacing as the bearing points with respect to the two partner balls. The balls are loose in a cage (Fig. 1B), i.e. combined or arranged without prestressing. This cage is preferably integrated into the rolling body structure. Depending on the loading case, of which some will be discussed hereinafter, the balls come into contact with the cage walls at support faces 5, but always at a speed-invariant point, so that the sliding friction resulting from the support effect is at a minimum.

Fig 1B shows the rolling element cage with (twice) three rolling element chambers 7, in this case receiving bores, in perspective for two ball triplets and in section through the channels in which can be housed a ball triplet, as shown in Fig. 1A. The represented configuration is reduced to such an extent that it essentially only represents one ball cage and a web-like member with a fixing opening 8 for fixing to another rolling body part. The rolling body is a sub-rolling body, and as will be described hereinafter a plurality of rolling bodies can be combined into one.

Fig 1C shows the rolling element cage in cross-section in the vicinity of the ball centre of a ball triplet housed therein. It is here possible to see details such as the inward deformations 10 of the chamber bores 7 at the outside, which keep the balls 3 trapped in their bores. Depending on the material used, e.g. in the case of POM (polyoxymethylene), a plastics material from the polyacetal group which is characterized by high surface hardness and good wear characteristics, the elasticity of the material ensures by means of such a deformation that

the ball can be forced through the somewhat smaller entry diameter and snaps into the receiving bore. It is also possible to see the cage bearing points 5 with which the cage is supported on the rotation centres of the rolling balls 3. The actual rolling body runs with its rolling elements along rails, which are arranged in the form of ball rails 6 in the guide channel 4 of guide rail 2.

Fig. 1D shows in perspective a preferred embodiment of a raceway profile for a guide channel in a guide rail. The rolling body cage in Fig. 1B matches this. It is possible to see three inclined beds for rails with slots 6' for receiving in each case two ball rails 6, on which the balls 3 of the rolling body 1 can roll. The rail members inserted in the beds are preferably provided with flat contact faces, so that the balls contacting the surface of the rail members at one point can follow their path on said face corresponding to the instantaneous load application. In the case of flat rail members the tolerance between the balls, the housing and the actual rail members can be greater. When rail members with a curved contact face are used, the tolerances must be smaller.

Fig. 2A is a side view of a linear arrangement of individual rolling bodies 1, 1', 1" etc., which in each case contain two ball triplets. Such arrangements can be combined in a random manner and/or can be randomly interconnected. For example, with an elastic connection between the rolling body elements, they can be combined to form a rolling chain. With such rolling chain bodies with rolling body elements which only have one triplet, guides with relatively small curve radii can be obtained, so that the rolling body according to the invention can also be

advantageously used in chain conveying, in which conveying takes place in all directions in space. In place of the rail members, the guide channel surface can be directly used for ball rolling, particularly if a metal profile is used for the guide channel.

Fig. 2B shows another variant as to how rolling bodies can be used in the form of sub-elements. Two rolling bodies 1,1' each with one ball triplet are rigidly interconnected by means of a web 11 and in this way form a rolling body for a curving longitudinal guide. The fixing means 8,8' can, if desired, be constructed as a pivot bearing with pins in the bore. This example shows how extremely universally the described rolling body can be used.

A further possibility of universal usability is shown by the lining up of rollingbodies in Fig. 2C. Each rolling body 1,1',1" has on its rolling element cage a guide linkage 12 with a downwardly directed pin 8' and at the top on said cage a bush 8, in such a way that the pin can be inserted in the bush of a following cage and in this way forms a chain.

Fig. 3A shows a representation of a ball abstraction for discussing the kinematic conditions of such a rolling body. Three driving or driven groups AA, BB and CC comprise in each case one shaft a, b and c on which are arranged in each case two gear wheels, which are in engagement with one another or with the exterior at engagement points α, β, γ . Points β, β, β are transition points of the gear wheels from one group to the other and points $\alpha, \alpha; \gamma, \gamma; \beta, \beta$ are transition points from the rolling body to the outside on the guide rail members. In this case AA is a driving group and BB, CC are driven groups. Thus, a is the driven axle. Apart from the use of rotation arrows,

the rotational direction is also shown by vectors at right angles to the paper plane (a dot in a ring indicating an upwards direction, and a cross in a ring indicating a downwards direction). Thus at points β, β, β the rotational direction is into the paper plane, and on the periphery and at points α, γ out of the paper plane, so that the rolling body as a whole rolls into the paper plane or, in other words, would roll or drop downwards through its own weight in a vertical guide standing on the paper plane.

It can be seen clearly that the three wheel pairs with the engagement points α, β, γ behave in the same way as a gear which, rolling on itself, is able to roll along a path. On withdrawing the abstraction again, in which the individual gear wheels represented discs cut out of the ball, and forming the same into balls again, it can be seen that the three balls, in the case of isotropic force engagement rolling on one another, are able to roll along a path without sliding on one another or on one of the three rail members with the two ball rails. The balls ~~are~~ mutually support each other only at one point, where rolling friction occurs, which has a restraining action in opposition to the rolling direction, as in the case of rolling friction on the rails.

Fig 3B shows how an approximate balance is maintained with respect to the rolling friction of two balls 3 rolling on one another and moving forwards in a guide. Thus, if it is not systematically destabilized, the ball triplet is also not supported in an uncontrolled manner on the cage walls and does not produce there a sliding friction in uncontrolled manner. This would be the case with permanently supporting on a ball zone at higher

circumferential speeds, and brief momentary support effects of this type, which could occur with destabilization, must not last for a long time. Thus, the ball triplet must be capable of stabilizing itself also in the running direction during rolling. A rolling body triplet rolling in the indicated manner has a minimum of sliding friction, as shown by experiments.

Fig 3C also shows, again diagrammatically and based on Fig. 3A, a preferred arrangement of the ball rails with respect to the triplet balls, namely in such a way that the spacing $\alpha - \alpha$ of the rails of a rail member is the same as the spacing $\beta - \beta$ of the contact points with respect to the two partner balls. The rolling points α are at the location of the ball rail 6 indicated in the bottom part of the drawing. With the indicated triangular arrangement the rolling radii of all three balls are always the same. This leads to an identical circumferential speed of all the rolling balls, so that the force application always passes through the rolling axis and is therefore distributed over the rails in the ball channel in such a way that the ball cage does not have to absorb forces displacing the triplet. Thus, as stated, it is a rolling ball triplet.

In the case of non-use, i.e. outside of the guide channel, the balls are loosely mounted in a cage and are only secured against dropping out. The cage can be made from metal or plastics, the hardness of the material used being significant, because in the case of a loading of the balls it must also participate in this loading. The force coupled by the cage into the rotational centre is always transferred via two balls to the running channel having for each ball a rail with two bearing points (on the ball

rails). Thus, the cage is located on rotational centres of the balls, so that the latter are not exposed to greater friction than through the size of the spherical surfaces which form if the balls can be pressed into the cage walls. Where the cage must necessarily be supported on the triplet body, the ball surface speed is substantially zero, because the cage is supported on the rotation-invariant part of the ball and the sliding friction there must naturally be close to zero (corresponding to the spherical surface formed by the sunk cavity).

With reference to Figs. 4 to 7 and based on Figs. 1A and 1C, certain loading cases of the discussed rolling body in the guide channel will be investigated. For the resolution of the forces, use is made of a vector representation, whose sum vector is indicated as a thick arrow and whose partial vectors are shown as thin arrows. The force represented as a vector is directed in resolved form onto the points in the rolling body at which they act.

Fig. 4 shows the loading to a rolling body from above, i.e. it is pressed into the rolling body guide with the guide rails, and six of the possible nine contact points participate. In this loading case a lower ball Q is pressed against the two ball rails 6 of the rail member. It is simultaneously supported on two other balls S and R and attempts to force them apart. These two balls are consequently pressed against the ball rails of their rail members, so that the triplet is fixed between the rail members and the balls. Depending on the loading case, the balls are supported on only one or both rails (indicated respectively by a thicker dot). The rolling axis W of ball Q is horizontal (at right angles to the running

direction), and the rolling axes W of the two other balls R and S are inclined towards one another at an angle of 60° thereto and are substantially on an equilateral triangle. The cage, which in the case of non-loading is positioned relatively loosely around the triplet, is now supported on the points d of the two upper rotation centres D of balls R and S on the triplet (thicker dots). It can easily be seen that the rolling radii to the ball/ball and ball/rail member contact points are the same for all three balls. It is also possible to see how the forces are symmetrically subdivided over these application points. A symmetrical structure like the triplet is capable of subdividing all possible external force applications such that there is always a favourable ratio of high rolling friction to low sliding friction for the overall frictional resistance. The position of the rolling axis and the magnitude of the rolling radii always remain the same although, as stated, the balls can be supported on one or both rails.

Fig. 5A shows a force application attempting to draw the rolling body out of its guide channel, such as e.g. occurs in a purely suspended operation, three of the nine possible contact points participating. The two balls R and S are supported on their ball rails 6 and simultaneously relieve ball Q. In this force application, the latter is neither loaded by the rolling body cage, nor by one of the partner balls, and rolls in unloaded manner with them. The rolling body cage is supported on the two rotation-invariant points D of the now facing rotational centres of the two balls R and S. The two rolling axes W are precisely at 60° to one another, as in the loading case of Fig. 4. The rolling radii are identical, so that the two loaded balls have the same circumferential speed,

and also in this loading case only a very small mixed friction can be expected. The third, unloaded ball Q is located on the two partner balls in a suspended operation (but not in the operating case where there is an upward pull) and rolls on the same without participating in the force action.

On the basis of the special loading cage shown in Fig. 5A it is possible to construct an arrangement (not in accordance with the invention) with only two balls and which can be used for an overhead conveyor, and once again three of the possible nine contact points participate. However, this is a special case for an operating form, in which purely tensile loads occur at right angles to the guide channel. This arrangement is shown in Fig. 5B. The recess provided in Fig. 5A for ball Q is omitted, as is the rail member provided for said ball with the two ball rails in the rolling body guide. The rolling body cage now houses a rolling body pair instead of a triplet and rolls in accordance with the inventive method. For an overhead conveyor, for example, chains can be formed, which can be combined in either elastically flexible or articulated manner, as is recommended for the rolling body triplet. The force resolution under loading corresponds to that discussed in Fig. 5A and need not be discussed again here.

Fig 6. shows a loading case in which the guide 2 is pressed laterally on the rolling body 1 or the latter is pressed to the left against the guide, six of the possible contact points participating. This loading case occurs for example under the action of centrifugal forces, but the centre of gravity of the rolling body must be in the guide channel. However this loading case is discussed in order to show that the actually occurring mixed forms of

loads follow the same characteristics as shown in ideal form here. For clarity and for a better understanding the rolling body cage is widened by an angle on which the force is directed in such a way that it acts precisely on the triplet centre.

The rails of ball S press the latter against the two balls R and Q which, as in the two previous cases, are in each case pressed against the ball rail 6 of the particular rail member, so that the triplet can be stabilized. The force acts as if the rolling body were pressed from the right against the guide, so that the cage, indicated by the arrows of the vector system shown, is supported at three points d on the balls, namely in each case on one rotational centre D of a ball. As in the other drawings, D is the general rotational centre of a rolling element.

Fig.7 shows finally a loading case, according to which the force acting on the rolling bodies attempts to tilt (axially rotate) the same in its guide channel, six of the nine possible contact points participating. Such a tilting has a similar effect on the balls, rail members and cage to one of the previously described force applications to the longitudinal guidance system. As soon as one of the three balls is loaded by the pressure of the cage on one of its rotation centres, it imparts the force acting on it to the two partner balls via the rolling points, so as to take over part of the force and transfer it to the allocated rail members. As stated, this leads to a strengthening of the roller ball ball triplet, on whose rotational centres the cage is supported at three points. In this case the force application from the cage passes round the triplet balls on points d of rotational centres D, so that the torque shown, which attempts to

rotate the rolling body in the guide channel, is formed by the force guidance through virtually all the rolling axes.

Fig 8. shows an embodiment of a longitudinal guidance system, in which the rolling body guide is closed all around and surrounds in tubular manner a rolling body chain. This embodiment is intended to illustrate the universality of the inventive method and the construction possibilities derivable therefrom. However, it is only shown here after discussing the various loading cases and no further special consideration need be given thereto. Here it is a matter of a novel chain formed as rolling bodies, running in a closed guide and enabling forces to be axially transferred to a random spatial path. This longitudinal guide can be rigid or flexible, according to choice or the hardness of the material used.

Thus Fig. 8 shows to begin with a possibility as to how a rolling body can be placed in an all-round closed rolling body guide 2. A triplet with three balls 3 is arranged in a rolling body cage 1. The rotational centres or poles D, through which extends the rolling axis W, are supported on the faces 5 of cage 1. In slots 6' in the rolling body guide 2 are provided ball rails 6 on which the balls 3 roll. As discussed in connection with Fig. 1D, use is again preferably made of four or multi-edge rails instead of round rails, in order to provide a flat rolling path for the balls. This rolling path need only be sufficiently wide to lead to the "snakelike" path resulting from the overall tolerance and the varying force applications.

The rolling body guide 2 can e.g. be manufactured by continuous casting or extrusion and the rail members can

subsequently be drawn in again or also cast in the same operation. The rolling element cage with the rolling elements are connected either in flexible or articulated manner, if a curved configuration is required, but a rigid connection between two or more rolling bodies can also be a sought solution. This system is more suitable for a rigid construction than for a flexible construction.

A longitudinal guidance system with rolling body and rolling body guide constructed according to the indicated method can fulfil functions such as are fulfilled by known exclusively metallic longitudinal guidance systems with balls or other rolling bodies, when such materials are used. If metal and plastic are used, then longitudinal guidance systems are obtained, which are either inexpensive and/or lightweight or have other appropriate characteristics. If a particular mobility is sought, it can also be achieved with the proposed method and one of the proposed embodiments.

In the embodiments shown here, it is less a function of their intended use than the numerous possibilities provided by this teaching. This also applies to the embodiment fo Fig.8.

It is clear that in actual operation one or all the presently discussed force application cases and also mixed forms, can alternately occur in rapid sequence. It can be seen that each force application to the rolling body is always transferred in the direction of the rolling axes of the balls, i.e. partial forces are coupled in to the balls via the rotational centres. The thus loaded ball then rolls via the 2x2 points of rail member and partner balls. The frictional resistance consists of the rolling friction

of nine (not twelve) rolling bearing points and the sliding friction from 2 to 3 rotational centre points. Since the rolling friction, as explained in connection with Fig. 3B, keeps the triplet in balance in the paper plane and this balance is only briefly eliminated by disturbances in the rolling sequence, e.g. by positive/negative accelerations (impacts, vibrations, accelerations and decelerations), but is then restored again, it is also possible to add an "accidental" sliding frictional resistance to the "calculable" frictional resistance, but this can only be determined empirically and has not proved important during tests.

As shown by Figs. 2A, 2B and 2C, such triplet rolling bodies can be lined up in random form. A ball cage is not much wider than the diameter of the balls used, so that such a rolling body is relatively small. If a plurality of such rolling bodies is connected by an articulated or elastic connection, one can make a chain which rolls surprisingly easily in its guide, and which is e.g. very suitable for a chain conveyor. If in the case of a conventional chain conveyor the chain is pushed or drawn through the guide channel, considerable sliding resistances occur, which must be reduced by the use of lubricants. These sliding resistances also constitute a limit for the chain conveyor length. It is clear that in the case of a chain formed from the proposed rolling bodies the use of lubricants is not decisive and a chain sliding in a channel has nowhere near such a low resistance as a chain rolling in its channel.



CLAIMS

1. A longitudinal guidance apparatus having a rolling body guide (2) and a rolling body (1) guidable therein, in which in the rolling body are arranged rolling elements (3) and support faces (5) for coupling in loading forces, the rolling body guide (2) being a guide channel (4) with rail members for receiving the rolling elements, wherein the rolling body (1) has at least one integrated rolling body cage in which three rolling elements (3) are arranged in recesses (7), the guide channel (4) containing for each rolling element (3) a rail member with rolling element rails (6) which are mutually so arranged that the connecting lines from the bearing point of a rolling element on its rail to a contact point between two rolling elements form an obtuse angle, and at least one support face (5) is provided in each recess (7) in the rolling element cage for each rolling element (3) in such a way that a line perpendicular to this support face (5) is also substantially perpendicular to the connecting line from the bearing point of the rolling element (3) on its rail to the contact or rolling point between two rolling elements (3).

2. Apparatus according to claim 1, wherein in the recesses (7) in the rolling element cage for each rolling element (3) are provided two facing support faces (5).

3. Apparatus according to claim 1 or claim 2 in which the rolling element cage has three recesses (7) arranged in a plane, which pass into one another and into which are integrated support faces (5), which are inclined to one another by an angle of 120° and which serve to receive or



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- 24 -

support in each case one rolling element (3).

4. Apparatus according to claim 3, in which the rolling elements (3) are balls.

5. Apparatus according to claim 3 or claim 4, in which the rolling element cage is made from a softer material than the rolling elements.

6. Apparatus according to any one of claims 3 to 5, in which the outer opening (10) of recesses (7) for receiving the rolling elements (3) cross-sectionally tapers inwardly below the largest cross-section of the rolling element, in such a way that a rolling element (3) can be trapped in the recess (7).

7. Apparatus according to claim 5 or claim 6, in which the cross-sectional taper is so dimensioned and the rolling element cage material is so selected, that the rolling elements can be introduced or snapped in from the outside by pressure in the recess.

8. Apparatus according to any one of the claims 3 to 7, in which there are at least two rolling element cages with their associated sets of three rolling elements in a rolling body (1).

9. Apparatus according to claim 1 or claim 2, in which the rail members are set at an angle of substantially 120° to one another.

10. Apparatus according to claim 9, in which each rail member substantially comprises two parallel rolling element rails (6).



11. Apparatus according to claim 8 or claim 9 in which the rolling element rails are made of a harder material than the remainder of the guide channel.

12. Apparatus according to any one of the claims 9 to 11, in which the rolling body guide (2) is closed all-round and is provided at equi-angular distances with rail members with rolling element rails (6).

13. Apparatus according to any one of claims 3 to 12, in which a plurality of rolling bodies is used in a rolling body guide.

14. Apparatus according to claim 13, which the lined up rolling bodies (1) are interconnected in elastically flexible or articulated manner.

15. Apparatus according to claim 13 or claim 14, in which the rolling body guide (2) is closed all-round and is provided at equi-angular distances with rail members with rolling element rails (6), the rolling elements guided therein comprising a plurality of sets of three balls.

16. A longitudinal guidance apparatus having a rolling body guide and a rolling body guidable therein substantially as herein described with reference to, and as shown in Figures 1 to 4, 5A and 6 to 8 of the accompanying drawings.
