SPECIFICATION

Axial/rotary guide element

The object of the present invention is a guide element for rotary movement and/or unlimited linear movement involving contact with balls on a smooth shaft, comprising an external sleeve and an internal tubular casing that is either fixed relative to the sleeve or can rotate freely relative to the sleeve and which comprises tracks in the form of closed circuits formed by two longitudinal rectilinear portions extending through the wall of the casing and joined to one another by curved portions at their ends, these circuits being provided with balls that effect contact between the shaft and the bore of the sleeve.

Elements for linear guidance of a cylindrical element involving contact with balls circulating on a shaft are known under various names, such as axial bearings, linear bearings and ball-bearing boxes. These names generally refer to the same object, namely guidance of a cylindrical element by means of balls on a shaft, the balls being recycled in endless closed circuits, which gives an unlimited linear movement to the element. In the particular case where a rotational movement is desired separately from or at the same time as the translational movement, recourse is made to so-called axial and rotary bearings or linear rotary bearings. At the present time two types of bearings permitting a rotation and an unlimited translational movement are available on the market.

The main disadvantage of the so-called "two bearings" principle, which consists of mounting a needle bearing or a radial ball-bearing on the exterior of a linear bearing with circulating balls is that its external dimensions are too large for small elements.

The principle of alternating contact and circulation of balls in a casing involves a casing which consists of an external cylindrical sleeve comprising, in its bore, disengagement sections and working sections, the latter effecting contact with the shaft via balls arranged in closed circulation circuits made in a freely rotatable tubular casing situated in the sleeve and positioned axially relative to the sleeve by stop means. Rotation is made possible by alternating contact between the working sections and the balls in the rectilinear parts of the circuits of the casing if the reciprocal angular values are in accordance with a law utilising a geometrical aperture in a general combination. This system is effective for high precision axial and rotary guiding systems, but its defects include a limit on the load capacity, rotatational speed and high manufacturing costs, and in addition a large number of ball-circuits are necessary to enable it to be realised geometrically. Furthermore, this element is difficult to manufacture with small dimensions.

The object of the present invention is to obviate these disadvantages and provide an element for unlimited linear displacements on a shaft, accompanied or not by a rotational displacement, having the following characteristics:

- a simple construction involving a minimum number of parts and balls
- low manufacturing costs
- high load capacity
- little variation in the load capacity regardless of the movements during use
- small overall dimensions
- well suited to rotational speeds
- good reliability
- good guiding precision
- an internal geometrical arrangement enabling the element to be manufactured having small dimensions.

The guide element according to the invention is characterised in that the sleeve comprises a continuous cylindrical bore in its interior, and the casing is provided with at least three separte closed ball-circulation circuits, all the balls of at least one circuit forming a group of balls of different diameter compared with the balls of the other circuit or circuits.

According to a preferred embodiment, the casing is provided with three closed ball-circuits, one of the circuits being provided with balls similar to one another but whose diameter is smaller by a factor of 1/10 to 1/100 of the average diameter of the balls of the two other circuits. The three circulation circuits may form an angle of 120° with one another.

According to another embodiment, the casing is provided with four closed-ball circulation circuits, two of these circuits being provided with balls similar to one another but whose diameter is smaller by a factor of 1/12 to 1/120 of the average diameter of the balls of the two other circuits. In this embodiment involving four circulation circuits, two of the straight lines each forming part of two circuits may form between one another an angle at the centre of 110°, the two other straight lines of the two other circuits forming with one another an angle at the centre of 80°, the bisectrix of these angles passing through a plane of symmetry of the element.

The casing may comprise more than two separate groups of ball-diameters and/or may include more than four closed ball-circulation circuits.

The sleeve may be in the form of a cylindrical collar held between two end caps integral with the casing, the length of the collar being substantially equal to the length of the rectilinear portions of the ball-circulation circuits and the balls located in the end curved portions of the circuits being positioned radially by tunnels made in the end caps, the internal front face of each of the caps producing a frictional force acting against the corresponding front faces of the collar.

The drawings illustrate, by way of example, several embodiments and variants of a guide element for rotary and/or unlimited linear movement involving contact with balls on a shaft according to the invention.

In the drawings:

Figure 1 is a radial section through a first embodiment of an element in a form comprising four ball-circulation circuits;

Figure 2 is a side view, partially in section, of the embodiment of Figure 1;

Figure 3 is a front view, partially in section, of the

embodiment of Figures 1 and 2;

Figure 4 is a radial section through a second embodiment of an element in a form comprising three ball-circulation circuits;

Figure 5 is a side view, partially in section, of the embodiment of Figure 4, and including an axial retention of the casing by a system involving two balls at 180°;

Figure 6 is a front view partially in section, of the embodiment of Figures 4 and 5;

Figure 7 is an axial section of a variant of an element in which the straight lines of the ball-circulation circuits are inclined with respect to the generatrices of the casing and a work discharge spiral is provided in the bore of the sleeve, the said sleeve having two external diameters conferring a self-aligning character to the element.

Figure 8 illustrates a form of assembly in a tubular member balancing the eccentric of a pair of elements of an embodiment shown in Figure 9 and comprising a sleeve having a self-aligning character, the elements being joined to one another by a tie member indexing, in an inverse polar position, the casing of the elements;

Figure 9 illustrates an element in the variant comprising a polar indexing system for the casing;

Figure 10 illustrates a form of assembly of two elements of Figure 9 with a plurality of tie members indexing the casings in the same polar position;

Figure 11 illustrates a ball-race comprising the polar indexing system of Figures 8 to 10;

Figure 12 illustrates a tie member;

Figure 13 is a side view, partially in section, of a first variant of the embodiments of Figures 1 to 6;

Figure 14 is a front view, partially in section, of the first variant of Figure 13;

Figure 15 is a side view, partially in section, of a second variant of the embodiments of Figures 1 to 6, and

Figure 16 is a front view, partially in section, of the second variant of Figure 15.

The guide elements for rotary and unlimited linear movements illustrated in Figures 1 to 6 comprises an external sleeve 1, a tubular casing 2, balls 6 and 7, a shaft 8, and means 9 for axially retaining the casing 2 relative to the sleeve 1. The external sleeve 1 comprises a cylindrical bore 3 not containing any working and disengagement sections, as is the case in sleeves of the prior art. This working contact bore 3 is thus continuous over the whole of the circumference of the sleeve 1. The casing 2, which can rotate freely, is situated within the sleeve and comprises at least three closed circuits 4 for circulation of balls wherein these circuits 4 consist of two longitudinal rectilinear portions that extend through the wall of the casing 2 and are connected at their ends by curved portions 5.

For a better understanding of the construction and operation of the element, each circulation circuit 4 for balls is formed by a contact or load rectilinear portion called "a" and by a discharge or recycling rectilinear portion called "b"; moreover, the closed circulation circuits are divided ingo two categories (see Figures 1 and 4), namely category "x" and category "z", the circuit or circuits of category "x" being provided with balls 6 all of the same diameter but slightly smaller than the diameter of the balls 7 of the circuits of category "z". Furthermore, the longitudinal rectilinear portions "ax and az" will be termed contact rectilinear portions, and the rectilinear portions "bx and bz" will be termed recycle rectilinear portions.

In the second embodiment of Figures 4 to 6, the element is provided with three closed circuits 4 for circulation of balls (see in particular Figure 4), one circuit being of category "x" and the other two circuits being of category "z", which produces a contact rectilinear portion termed "ax", the other two contact rectilinear portions being termed "az". In this realisation the three contact rectilinear portions "lax + 2az" form an angle at the centre of about 120° with respect to the circumference of the casing. The two recycle rectilinear portions "bz" are located close to one another and form an angle at the centre of at most 30°, the bisectrix of this angle being the same as the bisectrix of the angle of 120° at the centre formed by the two contact rectilinear portions "az", the recycle rectilinear portion "bx" being situated approximately diametrically opposite either of the two contact rectilinear portions "az". In this realisation the difference in diameter between the balls 6 of the circuit of category "x" and the diameter of the balls 7 of the circuits of category "z" is between 1/10 and 1/100 of the average diameter of the balls of the other two circuits.

In the first embodiment of Figures 1 to 3, the element is provided with four closed circuits 4 for circulation of balls, two of these circuits being of category "x" and the other two circuits being of category "z", which produces two contact rectilinear portions termed "ax", the two other contact rectilinear portions being termed "az". In this relisation the two contact rectilinear portions "az" form an angle at the centre of about 110° with respect to the circumference of the casing, the two contact rectilinear portions "ax" forming an angle at the centre of about 80° with respect to this circumference. Furthermore, an axis of symmetry of the element passes through the bisectrices of these angles. The two recycle rectilinear portions "bz" are situated close to one another and form an angle at the centre of at most 30°, the bisectrix of this angle being centred on the bisectrices of the aforementioned angles at the centre of 110° and 80° formed by the contact rectilinear portions "az and ax", the two recycle rectilinear portions "bx" forming an angle at the centre of about 170°, whose bisectrix is centred on the bisectrices of the afore-described angles. In this realisation the difference between the diameter of the balls 6 of the circuits of category "x" and the diameter of the balls 7 of the circuits of category "z" is between 1/12 and 1/120 of the average diameter of the balls of the other two circuits.

By virtue of the angular arrangement of the longitudinal rectilinear portions of the ball-circuits and by virtue of the difference in diameter between the balls of certain of these circuits, there is a small decentring "e" of the bore 3 of the sleeve 1 with respect to the shaft 8 (see Figures 1 and 4). This decentring "e" serves to produce a radial clearance

"Δ" sufficient to enable the return circulation of the recycle rectilinear portions "bx and bz". In actual fact, this radial clearance "Δ" rotates together with the casing, and on account of the general geometrical arrangement of the rectilinear portions for the balls this clearance "Δ" exists only for the balls of the rectilinear portions of group "b", the rectilinear portions of groups "a" having their balls in working contact at suitable angular positions between the bore 3 of the sleeve 1 and the shaft 8.

A calculation of the value "Δ" defined as being the clearance between the internal bore of the sleeve 1 and the top of the balls of the rectilinear portions "b" in two examples of elements gives the following numerical values:

Arrangement with three circulation circuits for balls situated angularly according to the example of Figures 4 to 6.

- Diameter of the shaft = 12 mm.
- Diameter oof the balls of the circuit "x" = 2.381 mm.
- Diameter of the balls of the circuits "z" = 2.5 mm.
- Diameter of the bore of the sleeve = 16.922 mm.
- Decentring "e" = 0.079 mm.
- Clearance "Δ" for the balls of the rectilinear portions "bz" = 0.039 mm.
- Clearance "Δ" for the balls of the rectilinear portions "bx" = 0.04 mm.

Arrangement with four ball-circulation circuits arranged angularly according to the example of Figures 1 to 3.

- Diameter of the shaft = 12 mm.
- Diameter of the balls of the circuits "x" = 4.0 mm.
- Diameter of the balls of the circuits "z" = 4.170 mm.
- Diameter of the bore of the sleeve = 38.195 mm.
- Decentring "e" = 0.129 mm.
- Clearance "Δ" for the balls of the rectiliner portions "bz" = 0.053 mm.
- Clearance "Δ" for the balls of the rectilinear portions "bx" = 0.088 mm.

It should be noted that the ratio "Δ" may be taken as approximately e/2 in the arrangement involving three circuits, and that this latter arrangement is relatively better geometrically than the arrangement involving four circuits.

Since practical tests have demonstrated that a radial gap "Δ" having a value of 1/120 of the diameter of the balls is sufficient to allow a recycle passage of the balls of the rectilinear portions "b", the result is a new system that justifies what would have seemed impossible hitherto, namely to have a rotary and unlimited linear bearing involving circulation of balls by recycling without alternating conact with successive angular working sectors, this moreover with a small number of balls situated on a single working floor, these balls together ensuring a guiding contact for all the required movements. When the element rotates with respect to the shaft, it behaves like a conventional ball-bearing system, the casing rotating at a differential velocity. If the element undergoes a translational movement, the balls circulate in the races and pass along the curved portions of the circuits of the rectilinear portion "a" to the rectilinear portion "b". When the element is subjected to a combined axial and rotary movement, the balls rotate together with the casing and circulate in the circuits, the balls in working contact rolling in the direction of the resultant movement. The contact of the working balls is continuous despite the rotation, and the element thus suffers virtually no change in load capacity irrespective of its rotation. It should also be noted that the circulation of the balls always takes place in one direction in direct relation to the reciprocal displacement of the shaft and sleeve, irrespective of the angular movements. Moreover, when the element undergoes axial and rotary movement, the absence of working sectors and disengagement sectors in the sleeve enables the element is withstand high rotational velocities and imparts a good resistance to wear and tear, the balls being renewed by recycling and rolling, under working conditions, on continuous surfaces.

Furthermore, the described elements are particularly advantageous from the point of view of geometry when they involve three or even four ball-circulation circuits, this small number favouring low manufacturing costs, the more so as the casing may be moulded from a plastics material, such as polyamide and the balls do not have dimensions restricted by too small an angular space. The aforementioned advantages relating to the embodiments of Figures 1 to 6 are effectively absent in the axial-rotary elements of the prior art involving alternating contact.

In addition, the element according to the invention may be manufactured having small dimensions, for example shaft diameters of 4 mm, the external diameter of the element being at most 8 mm. This particular feature is novel for a rotary and unlimited axial guide system involving contact with balls, and give rise to possible future applications in fields such as mecanography, automation, electronics, aeronautics and other disciplines.

According to the embodiment of Figures 1 to 3, the balls are displaced from the shaft during passage in the curved portion of the circuits at least one of their ends, and at this point they follow a substantially circular disengagement path in the form of a truncated cone in the interior of the sleeve and circulate on ascending and descending ramps in the casing in such a way that the tops of the balls are at a uniform radial distance in the groove of the sleeve. In order to enable the element together with the casing, previously equipped with its balls, to be installed, the said casing can be inserted into the sleeve only if the balls ascend radially in the curved portions of only one end of the casing. On account of this fact, the central parts of the circuits can only be connected to the whole casing at one end, or in a variant at two ends, the connecting tongue of one end then being of small cross-section.

According to a variant (not shown), at least one of the ends of the ball-circuits may have more than one tongue for example, two tongues, the casing being intersected in the middle of the right-hand curved

portion 5 of the circuit of Figure 2. Circuits having three tongues will, for example, be used for guide elements of large dimensions.

Since the tubular ball-casing 2 is located between the bore 3 of the sleeve 1 and the shaft 8, it may be located radially by these two references, an adequate clearance being provided. The casing may be positioned axially relative to the sleeve by frictional end stop means 9 or by ball-bearing stop means, now shown.

In the embodiment of Figures 4 to 6, the casing 2 is terminated longitudinally by means of two balls 10 of larger diameter than the diameter of the working contact balls, these two balls 10 being located in a seating 11 intersecting the wall of the casing opposite the circular groove 12 in the sleeve 1. These balls 10 position the casing axially, and engage with a small radical clearance in the circular groove 12 of the sleeve and are kept radially in place by the shaft 8 when the element is operating. This solution eliminates retaining frictional forces during a rotational movement and enables the casing to have exactly the same length as the sleeve, installation being simple with a casing made of plastics material since the retaining balls 10 can be introduced by deforming the inlet of their seating 11 from the inner side of the element. Furthermore, in order to benefit from an invariable radial clearance and the fact that they are of the same dimension, these two balls are placed at 180° with respect to one another on an axis of the element perpendicular to the dirction of the artificial decentring "e".

In the variant of Figure 7, the rectilinear portions of the circulation circuits 4 are slightly inclined with respect to the generatrices of the casing, all the working rectilinear portions "a" being parallel to one another, which permits a favrouable rolling distribution when the element functions purely in a linear manner, each working ball rolling on its own track. Nevertheless, the angle of inclination or helical angle γ may be at most 10° relative to the axis of the element, this mode of construction increasing, by virtue of the impossible geometric conditions, the load constraint on certain balls of the contact rectilinear portions "a". The result is a reduction in the load capacity of the element.

Figures 1 to 6 illustrate an embodiment comprising 3 ball-circulation circuits and an embodiment comprising 4 such circuits. It is clear to those skilled in the art that the elements described are not restricted to these two possibilities, and that elements comprising 5 circuits, or even more than 5 circuits may be elaborated. Moreover, more than two different categories of circuits may be employed. For example, three categories of circuits may be provided, each category being equipped with balls of a different diameter.

The elaboration of the elements that have just been described is made possible by virture of the decentring of the sleeve relative to the shaft by means of the intermediate unit creating this decentring "e", and this intermediate, namely the casing with its circuits of balls of different dimensions, positions relatively two cylindrical surfaces. According to the embodiment, at least two rectilinear portions of balls roll on the reflection of the surfaces tangential to the shaft and to the bore of the sleeve, making a slight angle with respect to one another, and these balls will thus tend to deviate from the working direction during a linear displacement on account of the lateral resultant forces in the direction of movement. In normal use this extraneous effect may be regarded as negligible, and since the length of working contact of the sleeve is relatively short the balls are no longer subjected to this effect during recycling, and the deviation is thus cancelled each time the balls leave working contact. However, this effect is inconvenient if the element operates only over a short alternative course, which is why in one variant this disadvantage may be cancelled by providing the bore of the sleeve with a spiral 16 (Figure 7) of small width and depth that alternately discharges the working balls, the pitch of this spiral 16 being such that contact is lost over only one ball at a time in the rectilinear portion "a".

Moreover, during continuous rotary use in a single direction, by virture of the relationships of the circumferences between the bore of the sleeve, shaft and the different sizes of balls, the latter being arranged in a planetary system, the balls of small diameter will tend to overtake the balls of large diameter in the direction of rotation. This effect is cancelled in normal use where the balls recycle in a movement that is also sufficiently large linearly. In other cases the variant involving the spiral 16 cancels this effect. It should be noted that the relative differential velocity of the centre of gravity of the balls of different dimensions is in any case slight, the ratios of the circumferences of the balls 6, balls 7, shaft and bore of the sleeve giving a traversed path almost identical to the two categories of balls in a normal situation.

The element according to the invention, despite its decentring "e", may be used in numerous applications, the value of the eccentricity in most cases being within the required tolerances for axial and rotary guiding, in particular in automation processes, handling processes, position stop means, and movement transmission processes. In many cases the low cost price, good load capacity, operating qualities and the fact that it can operate without lubricants means that such a guide element can advantageously replace guide systems involving smooth bushings and bushes. Any limits on the system reside rather in the manner of installation, and in fact if the element is used by itself, and the guidance is sufficient, the problem of the small decentring will be principle not arise, but if on the other hand two elements are installed in line in a bore, they will have to be made dependent on one another, which is why the two elements are in this case joined by one or more tie members of the tubular connection 13 (Figure 8) having the property of forming a modular unit enabling the elements to be installed at any desired interspacings. The tie members 13 have the particular feature of reciprocally locating the casings of the bearings at a predetermined angular position, and by virtue of this fact if two bearings have their casing in the same angular position the decentring of these two ele-

ments will be the same in the same direction, their axes will coincide, and the shaft working with these two guides will be situated in correct alignment conditions (see also Figure 10).

In one variant the exterior of the sleeve 1 has two diameters, the relatively short main diameter 15 conferring a self-aligning behaviour on the element in its mounting, the mutual working position of two elements with the same shaft being determined by this fact.

On combining the two solutions described above, it is possible using four elements having self-aligning characteristics and connected in pairs by a tie member 13 that positions each element of one pair at an inverse angular position, the pairs of elements being mounted in an external tube also having a self-aligning nature, to obtain in this particular case a perfectly concentric guidance using a common shaft (see Figure 8).

The tie members 13 have an inverse geometrical indexing system 14 at the two ends, at their image, the element casing 2 of this variant has the same indexing 14 at its ends, and consequently it is sufficient to turn the connected element in order to obtain an identical or inverse indexing (see Figures 8, 9, 10, 11 and 12). The shapes of the polar indexing means 14 of the casing end of the tie members 13 can be made simply if these pieces are produced from a moulded plastics material such as polyamide (see Figures 11 and 12). The tie members 13 are positioned radially by their internal bore, the diameter of which is slightly greater than the diameter of the shaft in conjunction with which the elements operate.

It should be noted that if two guide elements according to the invention are located at a sufficient mutual interspacing, they may in principle operate with the same shaft without the addition of an indexing system, the error due to the decentring "e" being absorbed by the adjustment tolerance of the shaft in the elements.

In the first variant of Figures 13 and 14, which may be an element involving three, four or a larger number of ball circuits for linear and/or unlimited rotary movement on a shaft 23, the sleeve is in the form of a steel collar 21 and the casing 22 serves to support two end caps 24 which enclose the collar 21. The tubular collar 21 has no disengagement sector and its bore 25 is perfectly circular and smooth, and of a constant diameter over its whole length. By virtue of this fact the manufacturing costs for this collar 21 are low compared with the relatively complicated sleeves of the axial and rotary bearings existing on the market. The element of Figures 13 and 14 is made from a casing 22 and the rotary caps 24 of plastics material. The result is an axial and rotary guide system of low cost price. In addition, the dimensions of the element are sufficiently small to enable it to be used in numerous applications.

The collar 21 is positioned under frictional forces in the centre of the casing 22 by means of the two caps 24 secured to this casing 22, a small clearance being provided between the faces 26 of the caps 24 and the faces 27 of the collar 21 so as to enable the latter to turn with respect to the casing-caps assembly. The casing 22 comprises at least three closed ball-circulation circuits 29, these circuits 29 consisting of two longitudinal rectilinear portions intersecting beyond the wall of the casing 22 and connected at their ends by curved portions 30. In these curved portions 30 the balls are distant from the shaft 23 in order to permit the existence of a section of material serving to maintain the central part 31 of the circuits 29. In order to permit this radial distancing of the balls, the caps 24 comprise, opposite the curved portions 30, tunnel-shaped recesses 32 dimensioned so that the balls situated in the curved portions 30 having an operating radial clearance between the bottom of the curved portions of the circuit and the cap 24. As shown in Figures 13 and 14 as well as in Figures 15 and 16 described hereinafter, the tunnel-shaped recesses 32 are parallel to the axis of the element opposite the curved portions of the ball-circuits. In a preferred realisation the caps are secured axially to the casing and are prevented from rotating by a combination of positive parts 33 and disengagement parts 34 in the caps 24 and at the ends of the casing 22, installation being made possible by elastically deforming the materials employed.

It is clear to those skilled in the art that the positive parts 33 and disengagement parts 34 provided in the caps 24 and at the ends of the casing 22 may be omitted or replaced by simple grooves and corresponding tongues. The caps may in this case either be bonded or welded to the ends of the casing.

The second variant of Figure 15 includes all the integers 21 to 34 described with regard to the variant of Figures 13 and 14. However, each of the end caps 24 has a band of elastomeric material 35 positioned for example in a groove 36 on the external diameter of each cap. These bands 35 serve to retain the casing 22/cap 24 assembly in the mounting, not shown, in which the element is fixed, which in this case becomes a ball-bearing guide arrangement for linear movement only. In this case the eccentricity "e" may be used to change a "inter axis" distance by turning the casing-cap assembly during installation in the mounting. These bands 35 may also serve generally to retain the element in a mounting (not shown) less precisely dimensioned or of larger dimensions.

By way of variation, it is possible to replace the bands 35 by means for preventing the casing rotating with respect to the sleeve. Moreover, the external diameter of the sleeve may be machined eccentric with respect to its internal diameter by the same amount as the decentring due to the differences in diameter of the balls in the circulation circuits. By positioning the casing in a suitable manner with respect to the sleeve and blocking it, the eccentricity of the element may then be eliminated, the element thus becoming an element for linear displacement only.

In the second variant of Figure 15, the steel collar 21 contains at its centre and on its exterior a short circular part 37 at the nominal adjustment diameter, this diameter 36 along being corrected. The element, combined or not with the bands of elastomeric material, in this case has a self-aligning property. In

addition to these advantages, this latter variant permits the rational utilisation of two elements that may be brought close to one another on the same shaft, the small eccentricity "e" being of no consequence for solutions of transmission of movement frequently encountered in industry and automation.

The element shown in Figurs 15 and 16 has ball-circuits 29 whose rectilinear portions are extended into the tunnels 32. The tongues forming the curved portions 30 constitute the start of the bend in the curved portion of the circuits, and then begin to rise relative to the shaft 23 as shown in Figure 16.

The variant illustrated in Figures 15 and 16 is an element comprising three ball-circuits and the caps (see Figure 16) have four tunnels 32, the two lower tunnels being symmetrical and only one being used in the variant of Figures 15 and 16. This feature means that only one cap need be used at the two ends of the casing.

The element according to the invention and described with regard to Figures 1 to 12 comprises a sleeve of hardened steel having a hardness of abou 62 RC, trued in its bore and on its exterior. The absence of working sectors and disengagement sectors in addition enables the interior to be machined by "honing", which substantially reduces the tooling costs involved in manufacture. The casing is, in a preferred embodiment, moulded of a self-lubricating plastics material such as graphite-containing polyamide 6. The balls are of chromium steel, their hardness is about 62RC, and their spherical accuracy and accuracy of diameter is of the order of a micrometre.

The element accoding to the invention can be realised from diameters of the shaft of the order of 3 to 4 millimetres, up to more than 50 millimetres. The diameter of the balls is betwen 1/4 of the diameter of the shaft for the smallest examples, and 1/9 of the diameter of the shaft for the large examples. The number of ball-circuits is three for the small examples and may be four for the examples where the diameter of the shaft ranges from 12 mm up to about 50 mm and above in the case of larger dimensions.

The working diameter of the shaft on the balls in the contact rectilinear portions is slightly prestressed on the shaft, being the maximum diameter of its tolerance, and for this reason the element is designed to operate with shafts having a tolerance of h6, such as are commonly found on the market.

The slight difference in the diameters of the balls of the different categories of circuits is often compensated by combining balls available on the market, and in particular by using metric dimensions on the one hand and imperial (inch) dimensions on the other hand, such as for example balls having a diameter of 1.5 mm with 1.588 mm = 1/16 × 25.4; 2.3812 mm = 3/32 × 25.4 with 2.5 mm; 3 mm with 3.175 mm = 1/8 × 25.4.

In a realisation, not shown, an even number of balls of two different dimensions may be placed in the circuits of the casing, independently of the category of the circuits, each large ball alternating with a small ball, the large balls ensuring working contact and the small balls serving as an intermediate and eliminating the friction caused by rotation of the balls in contact during a linear movement; nevertheless, this embodiment complicates the installation of the balls in the element and greatly reduces its load capacity.

In order to ensure a free circulation, the width of the tracks of the circuits has a value greater than about 1/10 of the diameter of the balls of these circuits, and on account of this fact circuits suitable for each category may be provided, also taking into account the multiple ball-diameter calculation for the whole length of the circulation track.

CLAIMS

1. A guide element for unlimited linear and/or rotational movement involving ball-contact on a smooth shaft, comprising an external sleeve, an internal tubular casing that is either fixed relative to the sleeve or can rotate freely relative to the sleeve, this casing comprising tracks in the form of closed circuits formed by two longitudinal rectilinear portions extending through its wall and joined to one another by curved portions at their ends, these circuits being provided with balls to effect contact between the shaft and the bore of the sleeve, characterised in that the sleeve comprises a continuous cylindrical bore in its interior, the casing is provided with at least three separate closed ball-circulation circuits, and all the balls of at least one circulation circuit form a group of balls of different diameter compared with the balls of the other circuit or circuits.

2. An element according to Claim 1, characterised in that the casing is provided with three closed ball-circulation circuits, one of these circuits being equipped with balls that are all similar to one another but whose diameter is smaller by a factor of 1/10 to 1/100 than the average diameter of the balls of the other two circuits.

3. An element according to Claims 1 and 2, characterised in that the casing comprises three rectilinear portions each forming part of one of the three separate ball-circulation circuits, these three rectilinear portions forming with one another an angle of 120° at the centre.

4. An element according to Claim 1, characterised in that the casing is provided with four closed ball-circulation circuits, two of these circuits being equipped with balls similar to one another but whose diameter is smaller by a factor of 1/12 to 1/120 than with the average diameter of the balls of the two other circuits.

5. An element according to Claims 1 and 4, characterised in that the casing comprises four rectilinear portions each forming part of one of the four separate ball-circulation circuits, two of these rectilinear portions forming with one another an angle of 110° at the centre, the two other rectilinear portions forming with one another an angle of 80° at the centre, the bisectrix of these angles passing through a plane of symmetry of the element.

6. An element according to Claim 1, characterised in that the casing comprises more than two groups of balls of different diameters.

7. An element according to Claim 6, characte-

addition to these advantages, this latter variant permits the rational utilisation of two elements that may be brought close to one another on the same shaft, the small eccentricity "e" being of no consequence for solutions of transmission of movement frequently encountered in industry and automation.

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The element according to the invention and described with regard to Figures 1 to 12 comprises a sleeve of hardened steel having a hardness of abou 62 RC, trued in its bore and on its exterior. The absence of working sectors and disengagement sectors in addition enables the interior to be machined by "honing", which substantially reduces the tooling costs involved in manufacture. The casing is, in a preferred embodiment, moulded of a self-lubricating plastics material such as graphite-containing polyamide 6. The balls are of chromium steel, their hardness is about 62RC, and their spherical accuracy and accuracy of diameter is of the order of a micrometre.

The element accoding to the invention can be realised from diameters of the shaft of the order of 3 to 4 millimetres, up to more than 50 millimetres. The diameter of the balls is betwen 1/4 of the diameter of the shaft for the smallest examples, and 1/9 of the diameter of the shaft for the large examples. The number of ball-circuits is three for the small examples and may be four for the examples where the diameter of the shaft ranges from 12 mm up to about 50 mm and above in the case of larger dimensions.

The working diameter of the shaft on the balls in the contact rectilinear portions is slightly prestressed on the shaft, being the maximum diameter of its tolerance, and for this reason the element is designed to operate with shafts having a tolerance of h6, such as are commonly found on the market.

The slight difference in the diameters of the balls of the different categories of circuits is often compensated by combining balls available on the market, and in particular by using metric dimensions on the one hand and imperial (inch) dimensions on the other hand, such as for example balls having a diameter of 1.5 mm with 1.588 mm = 1/16 × 25.4; 2.3812 mm = 3/32 × 25.4 with 2.5 mm; 3 mm with 3.175 mm = 1/8 × 25.4

In a realisation, not shown, an even number of balls of two different dimensions may be placed in the circuits of the casing, independently of the category of the circuits, each large ball alternating with a small ball, the large balls ensuring working contact and the small balls serving as an intermediate and eliminating the friction caused by rotation of the balls in contact during a linear movement; nevertheless, this embodiment complicates the installation of the balls in the element and greatly reduces its load capacity.

In order to ensure a free circulation, the width of the tracks of the circuits has a value greater than about 1/10 of the diameter of the balls of these circuits, and on account of this fact circuits suitable for each category may be provided, also taking into account the multiple ball-diameter calculation for the whole length of the circulation track.

CLAIMS

1. A guide element for unlimited linear and/or rotational movement involving ball-contact on a smooth shaft, comprising an external sleeve, an internal tubular casing that is either fixed relative to the sleeve or can rotate freely relative to the sleeve, this casing comprising tracks in the form of closed circuits formed by two longitudinal rectilinear portions extending through its wall and joined to one another by curved portions at their ends, these circuits being provided with balls to effect contact between the shaft and the bore of the sleeve, characterised in that the sleeve comprises a continuous cylindrical bore in its interior, the casing is provided with at least three separate closed ball-circulation circuits, and all the balls of at least one circulation circuit form a group of balls of different diameter compared with the balls of the other circuit or circuits.

2. An element according to Claim 1, characterised in that the casing is provided with three closed ball-circulation circuits, one of these circuits being equipped with balls that are all similar to one another but whose diameter is smaller by a factor of 1/10 to 1/100 than the average diameter of the balls of the other two circuits.

3. An element according to Claims 1 and 2, characterised in that the casing comprises three rectilinear portions each forming part of one of the three separate ball-circulation circuits, these three rectilinear portions forming with one another an angle of 120° at the centre.

4. An element according to Claim 1, characterised in that the casing is provided with four closed ball-circulation circuits, two of these circuits being equipped with balls similar to one another but whose diameter is smaller by a factor of 1/12 to 1/120 than with the average diameter of the balls of the two other circuits.

5. An element according to Claims 1 and 4, characterised in that the casing comprises four rectilinear portions each forming part of one of the four separate ball-circulation circuits, two of these rectilinear portions forming with one another an angle of 110° at the centre, the two other rectilinear portions forming with one another an angle of 80° at the centre, the bisectrix of these angles passing through a plane of symmetry of the element.

6. An element according to Claim 1, characterised in that the casing comprises more than two groups of balls of different diameters.

7. An element according to Claim 6, characte-

rised in that the casing is provided with more than four closed ball-circulation circuits.

8. An element according to Claim 1, characterised in that the rectilinear portions of the ball-circulation circuits are parallel to the axis of the element.

9. An element according to Claim 1, characterised in that at least one of the two rectilinear portions of the ball circulation circuits forms an angle with a generatrix of the casing.

10. An element according to Claim 1, comprising frictional retaining means for positioning the casing axially relative to the sleeve.

11. An element according to Claim 1, comprising ball-bearing stop means for positioning the casing axially relative to the sleeve.

12. An element according to Claim 1, comprising at least one ball located in a separte seating in the casing and intersecting its wall opposite an internal circular groove in the sleeve at at least one end of the element, for positioning the casing axially relative to the sleeve.

13. An element according to Claim 12, comprising two said positioning balls situated at 180° with respect to one another on an axis perpendicular to the bisectrix of the angle at the centre separating the two longitudinal working contact rectilinear portions of the two circuits equipped with the largest balls of the element.

14. An element according to Claims 12 and 13, characterised in that at least one internal circular groove in the sleeve serving for the passage of the curved portions of the ball-circulating circuits is the same circular groove that positions the balls for the axial positioning of the casing relative to the sleeve.

15. An element according to Claim 1 and any one of Claims 12, 13 and 14, characterised in that the casing has at at least one of its ends means for the polar positioning of an additional piece on the element.

16. An element according to Claim 15, characterised in that the polar positioning means are located at the two ends of the casing, the means at one end being in an angular position displaced by 180° with respect to the means at the other end.

17. An element according to Claim 15, characterised in that the additional piece for the element is at least one tubular tie member comprising means engaging with the polar positioning means for the casing.

18. An element according to Claim 1, characterised in that the external sleeve comprises, in its working bore, a spiral groove whose pitch is different to the diametr of the balls.

19. An element according to Claim 1, characterised in that the external sleeve is made of a previously hardened steel which is then trued on its external surface and in its interior bore.

20. An element according to Claim 1, characterised in that the external sleeve has two external diameters, the larger diameter having a length at most one quarter of the total length of the element.

21. An element according to Claim 1, characterised in that tongue members of the casing which join the centre part of the circulation circuits have a different cross-section at the two ends of the circuits.

22. An element according to Claims 1 and 21, characterised in that the centre parts of the circulation circuits are joined to the casing by three tongue members, two of these tongue members being arranged at one end of the circuits.

23. An element according to Claim 1, characterised in that the end curved portions of the circuits are connected to one another by a short rectilinear portion following the circumference of the casing, the circuit being formed by four 90° curved portions and four rectilinear portions.

24. An element according to Claims 1 and 10, characterised in that the sleeve is in the form of a cylindrical collar shorter than the element held between two rotary caps fixed to the casing, the internal front face of each of the caps producing a frictional force with the corresponding front faces of the collar, the whole assembly consisting of the casing and caps being free to rotate relative to the sleeve.

25. An element according to Claim 24, characterised in that the rotary caps comprise housings in the form of tunnels parallel to the element opposite the ball-circulating circuits.

26. An element according to Claim 24, characterised in that the rotary caps are secured to the casing by interengaging means, these means being of corresponding shapes.

27. An element according to Claim 1 or 24, characterised in that the casing and/or the caps are made of a plastics material such as polyamide.

28. An element according to Claim 24, characterised in that the rotary caps comprise housing means for at least one circular band of a flexible material on their external diameter.

29. An element according to Claim 24, characterised in that the collar comprises on its external diameter at least one circular groove for locating at least one elastomeric band.

30. An element according to Claim 1, characterised in that the external diameter of the sleeve is trued eccentric with respect to its internal diameter by a factor equal to the eccentricity created by the balls of different diameters in the circulation circuits.

31. An element according to Claim 1, characterised in that the sleeve is fixed relative to the casing so as to eliminate the eccentricity created by the balls of different diameters in the circuits.

32. A guide element substantially as hereinbefore described with reference to the accompanying drawings.

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