

Electric motor, lift with a cage movable by an electric motor, and lift with a cage and with an electric motor for movement of a guide element relative to the cage

The invention relates to an electric motor according to the introductory part of claim 1 and to a lift with a cage movable along a path by means of such an electric motor. A further subject of the invention is a lift with a cage movable along at least one guide surface, with a guide element which is arranged at the cage to be movable and which is brought into contact with the guide surface, and with an electric motor for movement of the guide element relative to the cage.

Electric motors of the aforesaid kind are known from European Patent Application EP 0 949 748 A1 and EP 0 949 749 A1. In these patent applications there are described linear motors which each comprise a primary part for producing a travelling magnetic field and a secondary part for providing a static magnetic field, wherein the secondary part and the primary part are physically separated by an air gap and are movable relative to one another under an action of the travelling magnetic field. For producing the travelling magnetic field the primary part comprises several flat air-core coils which are applied as printed circuits to an insulating substrate. The coils are connected in series in such a manner that they produce a magnetic field, which travels along a surface of the substrate, when an electric alternating current flows through the coils. For providing the static magnetic field several permanent magnets are arranged in the secondary part in such a manner that a periodic magnetic structure, which has a periodic reversal of the polarity of the respective magnetisation, is formed at a surface of the secondary part. This magnetic structure provides a static magnetic field with a periodic variation of the field strength. As coils for the primary part there are proposed several configurations which are constructed for supply with alternating current with one phase or with several phases. These linear motors have the disadvantage that the secondary part has a high weight due to being equipped with permanent magnets. Moreover, the use of permanent magnets leads to high piece costs, since on the one hand permanent magnets are usually comparatively expensive and moreover production of a secondary part composed of a plurality of permanent magnets is expensive and thus connected with high costs. The cost for production of the secondary part rises, with corresponding consequences for production costs, particularly when the permanent magnets have to correspond as precisely as possible in the dimensions thereof and have to be arranged parallel to one another with the greatest possible precision in such a manner that their surfaces form a flat surface.

The latter is relevant in the case of precision motors and in the case of high-efficiency motors having a narrow air gap between the primary part and the secondary part.

A lift with a drive system for a cage on the basis of a linear motor operated as a synchronous motor is disclosed in European Patent Application EP 0 785 162 A1. The linear motor comprises a primary part for producing a travelling magnetic field and a secondary part for providing a static magnetic field, wherein the secondary part and the primary part are physically separated by an air gap and are movable relative to one another under an action of the travelling magnetic field. The cage can be held at predetermined positions in a lift shaft or moved along a predetermined path solely by the linear motor, i.e. without co-action of further support means or a counterweight. The secondary part consists of a plurality of permanent magnets which are arranged at a wall of a lift shaft along the path of the cage. The primary part consists of coils which are arranged at a side of the cage and which, depending on the respective construction, can be controlled in two-phase or three-phase by alternating current in order to produce the travelling magnetic field. The cage is guided in such a manner that in the case of movement of the cage the primary part and the secondary part of the linear motor are movable relative to one another at a substantially constant spacing. In the present case the permanent magnets of the secondary part take up a relatively large area at the shaft wall. This construction of the secondary part thus leads to high material and production costs and the installation of the secondary part in the lift shaft is expensive due to the large weight of the permanent magnets. Since the secondary part provides permanent high static magnetic fields over the entire length of the lift shaft appropriate precautionary measures have to be taken during installation of the secondary part and generally during maintenance operations in the lift shaft in order to avoid undesired effects of the magnetic fields. This is expensive and accordingly disadvantageous.

Electric motors of the above-mentioned kind are used in lifts in order to be able to damp vibrations of a cage which can occur during movement of the cage transversely to the direction of movement. A lift with a cage is known from European Patent Application EP 0 731 051 A1 which is guided along guide rails by means of several roller guides. Each roller guide comprises three guide elements in the form of rollers which are each brought into contact with a respective guide surface on one of the guide rails and which roll over the respective guide surfaces when the cage is moved along the guide rails. The guide elements are each arranged to be movable relative to the cage. Each roller guide

comprises two linear motors by which the respective position of the guide elements with respect to the cage is controllable in such a manner that the cage is movable relative to the guide elements in two directions perpendicular to the direction of movement of the cage. Vibrations of the cage transversely to the direction of movement thereof are detected by inertial sensors. Depending on signals of the inertial sensors, a control causes the linear motors to move the guide elements in such a manner that compensation is provided each time for vibrations of the cage. Each linear motor comprises a primary part for producing a travelling magnetic field and a secondary part for providing a static magnetic field, wherein the secondary part and the primary part are movable relative to one another under an action of the travelling magnetic field. The primary part consists of two ferromagnetic lamination stacks with respectively the same shape. Each of the lamination stacks comprises three teeth which are arranged adjacent to one another and between which a respective groove is formed. Each of the lamination stacks carries a respective coil, the windings of which are laid around the centre tooth and through the grooves adjoining this tooth. The two lamination stacks are arranged in mirror image with respect to a plane in such a manner that the teeth of the lamination stacks are respectively disposed opposite one another in pairs and are separated by an air gap. Arranged in that manner, the lamination stacks together with the coils form an electromagnet with three pole pairs. In the case of a like-phase drive control of the coils by electric current there is produced in the lamination stacks a magnetic flux in such a manner that adjacent teeth of each lamination stack are respectively magnetised with different polarity. Correspondingly, in the case of a like-phase drive control of the coils with alternating current a magnetic field travelling between the teeth is produced in the air gap. The secondary part, influenced by this travelling magnetic field, of the respective linear motor can be moved. Each secondary part is movably arranged in the air gap between the two lamination stacks of the respective primary part and consists each time of the flat plate on which permanent magnets are arranged. In the present case the primary part of each linear motor is arranged in stationary position at the cage, whilst the secondary part of each linear motor is respectively connected with at least one of the guide elements. The construction of these linear motors is disadvantageous in many respects. The motors are, as a consequence not only of the mode of construction of the primary part, but also due to the mode of construction of the secondary part, bulky and heavy. This is disadvantageous, because typically eight linear motors are required for damping the vibrations of a cage. In the present case the linear motors significantly contribute to the overall weight of the lift. Due to the large weight of the primary part or secondary part of

the motors, high magnetic fields have to be produced between primary part and secondary part in order to achieve a predetermined acceleration. This is disadvantageous when rapid movements have to be regulated by these motors. Moreover, the width of the air gap between the lamination stacks is relatively large, since the permanent magnets of the secondary part have a relatively large space requirement. This is detrimental to the efficiency of the linear motors. Moreover, production of the primary part is expensive, since the manufacture of the lamination stacks and the windings of the coils are costly. A further disadvantage is to be seen in that a magnetic interaction exists between the permanent magnets of the secondary part and the lamination stacks of the primary part. This magnetic interaction can lead to occurrence of disturbance forces which make difficult a precise controlling of the position of the secondary part or of the movement of the secondary part relative to the primary part.

In US 2003/0000778 A1 there is disclosed a lift, the cage of which can be moved by means of a linear motor. The secondary part of the linear motor can comprise either wound coils or a combination of such coils and permanent magnets. Coils of that kind are usually wound on an iron core. The linear motor accordingly has a high weight and a large volume. Production thereof is, moreover, costly, since it has to be assembled from numerous individual parts.

It is the object of the present invention to avoid the stated disadvantages of the known electric motors and to create an electric motor which has a compact construction, has a low weight and brings therewith the precondition for economic manufacture. The electric motor shall - suitably dimensioned - be usable in a lift as a drive for movement of a cage or for movement of a guide element relative to the cage.

This object is met by an electric motor with the features of claim 1. The claims dependent on this claim define advantageous forms of embodiment of this electric motor.

The electric motor according to the invention comprises a primary part for producing a travelling magnetic field and a secondary part for providing a static magnetic field, wherein the secondary part and the primary part are movable relative to one another under an effect of the travelling magnetic field. The secondary part comprises a conductor track which is arranged on a substrate and which can be supplied with an electric current for the purpose of producing the static magnetic field.

The special construction of the secondary part enables provision of a static magnetic field without use of permanent magnets. The static magnetic field necessary for operation of the electric motor is produced electromagnetically in that an electric current is supplied by way of the conductor track. All disadvantages which accompany the use of permanent magnets are thus avoided.

According to the invention the secondary part comprises, as essential basic element, a substrate which serves as support for the conductor track and ensures the desired mechanical rigidity of the secondary part. The precondition is thereby created for construction of a secondary part which is compact, has a low weight and can be produced economically. The substrate and the conductor track can be constructed as a layered structure. The conductor track can be formed from, for example, a thin electrically conductive layer applied to a substrate and optionally suitably structured. With respect to construction and manufacture of the secondary part, technologies developed for printed circuits are in that case usable. This allows economic manufacture.

The substrate can be made from a material of high strength. This enables use of thinner substrates with a large surface. Thus, there can be created a secondary part which is extremely narrow in one dimension and thus can be moved through a particularly narrow air gap between two poles of a pole pair of a primary part. Since the conductor track can be formed from a thin, conductive layer, it is possible to create a secondary part which has a relatively smooth surface in the region of the conductor track. It is thereby possible to create an electric motor in which the secondary part can be arranged at a particularly small spacing from the primary part and which is accordingly operable with high efficiency.

The electric motor can be realised in a number of geometries. The shape of the substrate can - adapted each time to the shape of the primary part - be correspondingly selected. The electric motor can be constructed as, for example, a rotating motor. The electric motor can, however, also be designed for other forms of movement, for example as a linear motor. The substrate can have, for example, the shape of a cylinder. In this case the conductor track can be arranged on, for example, the circumference of the cylinder in order to form a secondary part rotatable about the longitudinal axis of the cylinder. The secondary part can also be constructed as a flat disc rotatable about an axis. In this case the basic surfaces of the disc are available for arrangement of the conductor track.

Alternatively, for example in the case of a linear motor, the secondary part can also be constructed as a flat plate movable along a track with a finite length, wherein the base surfaces of the plate are available for arrangement of the conductor track.

The secondary part of one form of embodiment of the electric motor according to the invention can be conceived as a layered structure produced by application of different layers on the substrate. The layers can be applied in succession and optionally suitably structured. In this manner three-dimensional structures of materials with different characteristics can be applied to the substrate. Individual layers can consist of an electrically insulating material or comprise regions of an electrically insulating material. The conductor track can be composed of conductor track sections respectively formed in different layers of the layer structure. Individual sections of the conductor track can cross over, for example, in different planes and be separated in the crossover region by an electrically insulating layer. Moreover, the possibility exists of arranging individual sections of the conductor track in different layers separated by an intermediate layer and providing in the intermediate layer an electrically conductive region which produces an electrical connection between these sections of the conductor track.

Layers of the stated kind can also be applied on both sides of the substrate and optionally structured. In the case of the secondary part of a further form of embodiment of the electric motor according to the invention it is provided, for example, that a first part of the conductor track is formed at a first surface of the substrate and a second part of the conductor track at a second surface of the substrate, wherein an electrical connection is produced between the first and the second part. This makes it possible to impart a particularly complex geometric structure to the conductor track.

In a variant of the secondary part at least one section of the conductor track can have, for example, the form of a coil, wherein each coil comprises one or more windings. The coil can be arranged on one side of a substrate, but it can also be composed of different sections of the conductor track which are arranged on different sides of the substrate and electrically connected together.

In a further variant of the secondary part several serially arranged sections of the conductor track can each have the form of a coil, wherein the coils are constructed in such a manner that, in the case of a current flow through the conductor track, adjacent coils

produce respective magnetic fields with different polarity. The conductor track can be arranged in such a manner that, for example, in the case of supply of the conductor track with a direct current there is produced at a surface of the secondary part a static magnetic field, the polarity of which has a periodic polarity reversal along the direction in which the secondary part is movable relative to the primary part. In this manner a secondary part for provision of a large number of magnetic poles can be constructed. With a suitable arrangement of the conductor track the area available on the substrate can be efficiently utilised. This is relevant for optimisation of the efficiency of the electric motor and the accuracy with which the movement of the secondary part relative to the primary part can be controlled during operation of the motor.

In a further development of the secondary part there can also be provided, for producing a static magnetic field, several conductor tracks which can be supplied with an electric current independently of one another. A static magnetic field with a particularly large energy density can be produced by a secondary part constructed in that way. On the basis of this concept, the maximum force with which the secondary part is moved relative to the primary part during operation of the motor can be additionally increased.

A further development of the electric motor according to the invention has a primary part which comprises a conductor track arranged on the substrate, wherein this conductor track can, for the purpose of producing the travelling magnetic field, be supplied with an electric current having a current intensity which varies with time. In the case of this construction of the electric motor the primary part can be realised according to the same technological concept on which the design of the secondary part is based according to the invention. For producing the travelling magnetic field there is thus provided an electrical structure which can be realised as a layered structure, for example by application of thin layers on a substrate and optionally by a structuring of these layers. For example, several serially arranged sections of the conductor track can each have the form of a coil, wherein the coils are constructed in such a manner that in the case of current flow through the conductor track adjacent coils produce respective magnetic fields with different polarity. Thus, not only the primary part, but also the secondary part can be realised as layer structures comprising thin electrically conductive regions applied to a substrate. Consequently, not only the primary part, but also the secondary part can be produced by techniques in use for fabrication of printed circuits.

This variant of the electric motor according to the invention has several advantages. Thin substrates, which additionally have a low weight, can be respectively used for the primary part and the secondary part. By contrast with conventional motor constructions, in the present case neither a ferromagnetic core nor wound coils nor permanent magnets are required for producing the magnetic travelling field or for producing the static magnetic field. This variant of the electric motor can accordingly be constructed to be particularly light, compact and favourable in price. The possibility within the scope of the invention of being able to realise the primary part and the secondary part without ferromagnetic cores and without permanent magnets also simplifies control of the movement of the secondary part during operation of the electric motor, since the interference forces which arise in the case of conventional electric motors between a ferromagnetic core (usually provided with teeth and grooves) and the secondary part are eliminated. Due to the low weight the motor is particularly well suited for control of rapid movements. Since only low masses have to be accelerated in the case of control of the motor, rapid movements can be controlled efficiently and precisely.

In a further development of the aforesaid variant of the electric motor according to the invention it is provided that the primary part comprises several conductor tracks arranged on a substrate and that each of these conductor tracks can for the purpose of producing the travelling magnetic field be respectively supplied with electric current having a current intensity varying with time. Since each of the conductor tracks can be controlled independently by a current source, an electric motor controllable in multi-phase can be devised in accordance with this concept.

The electric motor according to the invention can also be used in a lift as a drive for a cage movable along a path. The electric motor can be installed in the lift in such a manner that, for example, the primary part is arranged in stationary position along the path and the secondary part at the cage. Alternatively, the secondary part can be arranged in the stationary position along the path and the primary part at the cage. In addition, the lift can be equipped with means for guiding the cage along the path and the primary part and the secondary part can be arranged at these means in such a manner that the primary part and the secondary part are guided at a spacing from one another when the cage is moved along the path. The latter has the advantage that every movement of the electric motor and every movement of the cage are controlled by a common guide. A separate guide for the primary part or the secondary part of the electric motor can in this way be saved.

In a lift which comprises a cage movable along the guide surface and a guide element which is movably arranged at the cage and brought into contact with the guide surface the electric motor according to the invention can also be used as a drive for movement of the guide element relative to the cage. The electric motor can in that case be installed in such a manner that the primary part is arranged to be movable together with the guide element and the secondary part is arranged to be stationary with respect to the cage or that the secondary part is arranged to be movable together with the guide element and the primary part is arranged to be stationary with respect to the cage. Moreover, a control for the electric motor for reduction of vibrations of the cage, which can arise during movement of the cage, can be integrated in the lift.

Examples of embodiment of the invention are explained in the following on the basis of different schematic figures, in which:

- Fig. 1A shows a view of an electric motor according to the invention, with a primary part and a secondary part wherein the primary part is movable relative to the secondary part;
- Fig. 1B shows the electric motor according to Fig. 1A in a section 1B-1B;
- Fig. 2A shows a section of another electric motor according to the invention, with a primary part and a secondary part, wherein the secondary part is movable relative to the primary part;
- Fig. 2B shows the electric motor according to Fig. 2A in a section 2B-2B;
- Fig. 3A shows the primary part according to Fig. 1A in a detailed illustration;
- Fig. 3B shows the secondary part according to Fig. 1A in a detailed illustration;
- Fig. 3C shows the secondary part according to Fig. 3B in a section 3C-3C;

Fig. 4A shows a lift with a cage and a guide element for guidance of the cage and with an electric motor according to the invention for movement of the guide element relative to the cage;

Fig. 4B shows the electric motor according to Fig. 4A in a section 4B-4B;

Fig. 5A shows a lift with a cage and electric motor according to the invention as drive for movement of the cage; and

Fig. 5B shows the lift according to Fig. 5A in a section 5B-5B.

Fig. 1A shows an electric motor 10 according to the invention, which comprises a primary part 11 for producing a travelling magnetic field and a secondary part 12 for providing a static magnetic field. Fig. 1B shows the electric motor 10 in a section 1B-1B according to Fig. 1A.

Fig. 2A shows an electric motor according to the invention, which comprises a primary part 21 for producing a travelling magnetic field and a secondary part 22 for providing a static magnetic field. Fig. 2B shows the electric motor 20 in a section 2B-2B according to Fig. 2A.

The electric motors 10 and 20 are both conceived as linear motors. The primary part 11 and the secondary part 12 or the primary part 21 and the secondary part 22 are each so constructed that the primary part 11 is movable relative to the secondary part 12, or the primary part 21 movable relative to the secondary part 22, in the Z direction of a coordinate system XYZ, as indicated in Fig. 1A by a double arrow at the primary part 11 and in Fig. 2A by a double arrow at the secondary part 22.

The electric motors 10 and 20 essentially differ by the amount of the longitudinal extent of the primary part 11 or 21 and the secondary part 12 or 22 in the respective Z direction. In the case of the electric motor 10 the primary part 11 has, by comparison with a secondary part 12, a smaller length in Z direction. The electric motor 10 is therefore preferably usable in applications in which the primary part 11 (by contrast with the secondary part 12) has to be moved through a relative large distance. In the case of the electric motor 20, thereagainst, the primary part 21 has by comparison with the secondary part 22 a greater

length in Z direction. The electric motor 20 is therefore preferably usable in applications in which the secondary part 22 (by contrast with the primary part 21) has to be moved over a relative large distance.

The secondary part 12 comprises two devices 13, 13' which have the form of a rectangular plate and are arranged parallel to the Z direction at such a spacing from one another that they bound an air gap 18 of the width W. The devices 13 and 13' are respectively fastened to supports 15, which in turn are fixed to a base plate 16. The primary part 11 is shaped and arranged in such a manner that it is movable in the air gap 18 in the Z direction. A conventional guide (not illustrated in Figs. 1A and 1B) is provided in order to guide the primary part 11 in the Z direction during movement relative to the secondary part 12. The devices 13 and 13' each comprise electromagnetic means which are described in more detail in the following in connection with Figs. 3B-C and each serve for providing a static magnetic field. This magnetic field is usually produced in such a manner that it is present in the air gap 18, but in certain circumstances also on the sides of the devices 13 and 13' remote from the air gap 18. In order to concentrate a magnetic flux in a smallest possible space on the sides of the devices 13 and 13' remote from the air gap the supports 15 can be made of a soft magnetic material.

The secondary part 22 is constructed analogously to the secondary part 12 with respect to its structure and its function.

The secondary part 22 comprises two devices 23, 23' which have the form of a rectangular plate and which are arranged parallel to the Z direction at such a spacing from one another that they bound an air gap 28 of the width W. The devices 23 and 23' are respectively fastened to supports 25 which in turn are fixed to a base plate 26. The primary part 21 is shaped and arranged in such a manner that it is movable in the air gap 28 in the Z direction. A conventional guide (not illustrated in Figs. 2A and 2B) is provided in order to guide the secondary part 22 in the Z direction during movement relative to the primary part 21. The devices 23 and 23' each comprises electromagnetic means which are described in more detail in the following in connection with Figs. 3B-C and which each serve for providing a static magnetic field. This magnetic field is usually produced in such a manner that it is present in the air gap 28, but in certain circumstances also on the sides of the devices 23 and 23' remote from the air gap 28. In order to concentrate a magnetic flux in

a smallest possible space on the sides of the devices 23 and 23' remote from the air gap 28 the supports 25 can be made from a soft magnetic material.

The primary parts 11 and 22 respectively comprise electromagnetic means which are described in more detail in connection with Fig. 3A and which have the function of producing a travelling magnetic field. The said electromagnetic means are preferably so constructed that they are suitable for producing a travelling magnetic field in the Z direction.

Fig. 3A illustrates the primary part 11 in a plan view in the X direction. Fig. 3B shows - similarly in plan view in X direction - the device 13 or the device 13', which corresponds identically with the device 13. Fig. 3C shows the device 13 or 13' in a cross-section 3C-3C according to Fig. 3B along the polygon course characterised in Fig. 3B by the points A, B, C and D.

The primary part 11 comprises a substrate 30, on the base surfaces of which a conductor track 40 is applied. The conductor track 40 has two ends which are each connected with a respective electrical terminal 47 or 48. An electrical voltage U_p can be applied to the electrical terminals 47 and 48 in order to supply the conductor track 40 with an electric current I_p . The conductor track has two conductor track sections 41 and 42 which are respectively arranged on different sides of the substrate 30 and are connected together at their respective ends each time by way of an electrical connection 45. For clarification, the conductor track sections 41 disposed on the base surface of the substrate 30 facing the observer are illustrated by respective solid lines and the conductor track sections 42 disposed on the base side of the substrate 30 remote from the observer are illustrated by respective dashed lines. The conductor track sections 41 and 42 are connected in series in such a manner that several coils each with a respective winding are formed on the substrate 30. The coils are in that case lined up in Z direction to lie directly adjacent to one another. The conductor track sections 41 and 42 are connected in such a manner that adjacent coils are flowed through by the current I_p each time with opposite sense of circulation. In Fig. 3A the regions of the primary part 11 which lie within the respective winding on one of the coils are characterised in dependence on the respective sense of circulation of the current I_p by one of the symbols "I" or "II". In operation of the electric motor 10 the current I_p can be either a direct current or an alternating current. The magnetic field produced in the environment of the conductor track 40 by the current I_p has

a different (opposite) polarity each time in the regions distinguished by "I" and "II". If I_p is a direct current, then a static magnetic field arises which changes polarity in each instance on transition between the regions "I" and "II". If I_p is an alternating current, then the respective polarity changes as a function of time t and a travelling magnetic field arises which travels in the Z direction.

As Figs. 3B-C show, the construction of the devices 13 and 13' arranged in the secondary part 12 substantially correspond with the construction of the primary part 11 if the respectively different lengths of the devices 13, 13' or of the primary part 11 in the Z direction are disregarded.

The devices 13, 13' arranged in the secondary part 12 each comprise a substrate 50, on the base surfaces of which a conductor track 50 is applied. The conductor track 20 has two ends which are each connected with a respective electrical terminal 67 or 68. An electrical voltage U_s can be applied to the electrical terminals 67 and 68 in order to supply the conductor path with an electrical current I_s . The conductor track has conductor track sections 61 and 62 which are respectively arranged on different sides of the substrate 50 and are connected together at their respective ends each time by way of an electrical connection 65. For clarification, the conductor track sections 61 disposed on the base surface of the substrate 50 facing the observer are each illustrated in Fig. 3B by solid lines and the conductor track sections 62 disposed on the base side of the substrate 50 remote from the observer are each illustrated by dashed lines. The conductor track sections 61 and 62 are connected in series in such a manner that several coils each with a respective winding are formed on the substrate 50. The coils are in that case lined up in Z direction to lie directly adjacent to one another. The conductor track sections 61 and 62 are connected in such a manner that adjacent coils are flowed through by the current I_s each time with opposite sense of circulation. In Fig. 3B the regions of the device 13 or 13' lying within the respective winding of one of the coils are characterised, in dependence on the respective sense of circulation of the current I_s , by an arrow which indicates the respective sense of circulation of the current I_s and one of the symbols "+" or "-". In operation of the electric motor 10 the current I_s is a direct current. The magnetic field produced in the environment of the conductor track 60 by the current I_s is a static magnetic field and has a different (opposite) polarity each time in the regions distinguished by "+" and "-".

The regions "I" and "II" of the primary part 11 have the same length in the Z direction. The regions "+" and "-" of the devices 13 and 13' each have the same length in the Z direction. The secondary part 12 is matched to the primary part 11 to the extent that the regions "+" and "-" of the devices 13 and 13' have substantially the same length in the Z direction as the regions "I" and "II".

In order to move the primary part 11 relative to the secondary part 12 in operation of the electric motor 10 a direct current is selected as current I_S and an alternating current is selected as current I_P . In this case the primary part 11 and the secondary part 12 moved synchronously by the magnetic field generated by the current I_P and travelling in the Z direction along the primary part 11. Whether the primary part 11 is moved in the (+Z) direction or in the (-Z) direction opposite thereto is determined by the instantaneous phase position of the alternating current I_P in dependence on the instantaneous position of the primary part 11 relative to the secondary part 12. In order to prevent movement of the primary part 11 relative to the secondary part 12, several possibilities are available for selection: a direct current can equally be selected as current I_P or $I_P = 0$ or $I_S = 0$ can be realised. In order to control operation of the electric motor 10 each time a control (not illustrated in Figs. 1A-B and 3A-C) is accordingly provided which controls the current I_S and the current I_P with respect to the amplitude, phase position and frequency in each instance depending on the instantaneous position of the primary part 11 relative to the secondary part 12.

The substrates 30 and 50 can preferably be made of an electrically insulating material having a high strength, for example of a plastics material or a ceramic material. It is of advantage if the substrates 30 and 50 are made of a non-ferromagnetic material. In this case interference forces between the primary part 11 and the secondary part 12 can be avoided and thus the relative movements between the primary part 11 and the secondary part 12 controlled with a high degree of accuracy.

The construction of the devices 13 and 13' arranged in the secondary part 12 and of the primary part 12 can be modified in many ways within the scope of the invention. The conductor tracks 40 and 60 could each be covered by an insulating layer, for example in such a manner that the surfaces of the primary part 11 or of the devices 13 and 13' are formed by a planar insulating layer. The conductor tracks 40 and 50 could alternatively be guided in such a manner that the regions "I" and "II" and/or "+" and "-" are respectively

surrounded by conductor track sections which each form a coil with several windings. In addition, the said coils can also be formed by conductor track sections which are constructed merely on one side of the substrates 30 and 50. Coils with several windings can be constructed, for example, in layer structures of several layers which each comprise electrically conductive and electrically insulating regions. The different layers can be successively applied to the substrate 30 or 50 and optionally suitably structured.

The primary part according to Fig. 3A represents a simple example for a single-phase controllable primary part. Alternatively, the primary part 11 can also be provided with several conductor tracks which can be supplied with an electric current independently of one another. In this case different alternating currents with respectively different phase could be fed to the conductor tracks in order to produce a travelling magnetic field. The arrangement of the different conductor tracks arranged in the primary part 11 can be determined geometrically with respect to the arrangement of the regions, which are denoted by "+" and "-", of the devices 13 and 13' in order to optimise the electric motor. Concepts for optimisations of the primary part in that way are known from, for example, Patent Applications EP 0 949 749 A1 and WO 00/49702 A1.

The secondary part 12 comprises two devices 13 and 13' which are of identical construction and which are in addition arranged symmetrically with respect to the primary part 11. This arrangement has the advantage that during operation of the electric motor 10 no forces arise between the primary part 11 and the secondary part 12 which act perpendicularly to the Z direction (i.e. the direction in which the primary part 11 is movable relative to the secondary part 12). Alternatively, the secondary part 12 could also be replaced by a secondary part which has merely one of the devices 13 and 13'.

The above details with respect to the electric motor 10 according to Figs. 1A-B are transferrable in analogous manner to the electric motor according to Figs. 2A-B, wherein it is merely to be noted that the primary part 21 has a greater length extent in the Z direction than the secondary part 22. Correspondingly, the primary part 21 can have the same construction as the primary part 11 illustrated in Fig. 3A and the devices 23, 23' the same construction as the devices 13, 13' illustrated in Fig. 3B, with the significant difference that the primary part 21 should have by comparison with the devices 23, 23' a greater number of coils - respectively arranged one after the other in a row in the X direction - so that the secondary part 22 is movable along the entire length of the primary part 21 when a

magnetic field travelling in the Z direction along the primary part 21 is produced during operation of the electric motor 20.

Figs. 4A-B and 5A-B show two different uses for an electric motor, which is constructed in accordance with the invention, in a lift.

Fig. 4A shows an electric motor 90 which is constructed in accordance with the invention and which is installed in a lift 70. The lift 70 comprises a cage 71 which is guided along a guide surface 72' at a guide rail 72. Merely a part of the lift 70 in the immediate vicinity of the electric motor 90 is shown in Fig. 4A. A drive for moving the cage 71 along the guide surface 72' and other usual lift components are not illustrated. A guide device 75 is provided for guidance of the cage 71 along the guide surface 72'. The guide device 75 comprises: (i) a support 77 which is mounted at the cage 71; (ii) a guide element 76 which is constructed as a roller rotatable about a rotational axle 80; (iii) a lever 78 in which the rotational axle 80 is mounted and which is pivotable about a rotational axle 79 mounted in the support 77 and arranged at one end of the lever 78; (iv) a rod-shaped guide device 85 which is arranged at the support 77 and serves for guidance of the end of the lever 78 remote from the rotational axle 79; (v) a spring 86 which is arranged between the lever 78 and one end of the guide device 85 and biased in such a manner that the guide element 76 on each movement of the cage 71 along the guide rail 72 is brought into contact with the guide surface 72' and is pressed by a specific force (predetermined in specific limits) against the respective guide surface 72'. The guide element 78 can be moved relative to the cage 71 by means of a pivot movement of the lever 78 about the rotational axis 79. In the present case the guide element 76 rolls, in the case of movement of the cage 71 along the guide surface 72, on the respective guide surface 72'.

The electric motor 90 is fastened to the support 77 and the lever 76 in such a manner that the instantaneous position of the guide element 76 with respect to the cage 71 can be changed in electronically controlled manner with the help of the electric motor 90.

Fig. 4B shows the electric motor 90 in a section 4B-4B according to Fig. 4A. The electric motor 90 is designed as a linear motor and is constructed substantially like the electric motors 10 and 20. The electric motor 90 comprises a primary part 91 for producing a travelling magnetic field and a secondary part 92 for providing a static magnetic field. The secondary part 92 substantially corresponds with respect to its construction to the

secondary parts 12 and 22 of the electric motors 10 and 20, respectively. The secondary part 92 comprises two devices 93 and 93', which are constructed like the devices 13 and 13' and can be realised, for example, according to the layout indicated in Figs. 3B-C. Correspondingly, the devices 13 and 13' each comprise a respective conductor track which is arranged on the substrate and which can be supplied with an electric current for the purpose of producing a static magnetic field. The respective substrates are plate-shaped and have planar surfaces. The devices 93 and 93' are arranged parallel to one another and fastened to a support 95, which - as shown in Fig. 4B - has a U-shaped cross-section, in such a manner that an air gap is formed between the devices 93 and 93'. The primary part 91 is arranged to be movable in this air gap. The primary part 91 substantially corresponds with respect to its construction to the primary parts 11 and 21 of the electric motors 10 and 20, respectively. It can be realised, for example, according to the layout indicated in Fig. 3A. For producing the travelling magnetic field a conductor track, which is arranged on the substrate and can be supplied with an alternating current is, for example, provided. In the case of supply of the secondary part 92 with a direct current and in the case of supply of the primary part 91 with an alternating current the primary part 91 can be moved relative to the secondary part 92 (synchronously with the travelling magnetic field produced by the primary part 91). This movement takes place in the present case in the longitudinal direction of the guide device 85, as is indicated in Fig. 4A by a double arrow. As is illustrated in Figs. 4A-B, the secondary part 92 is fastened to the support 77. In addition, the end of the lever 78 remote from the rotational axle 79 is connected with the primary part 91 by means of a connecting element 89. Correspondingly, in operation of the electric motor 90 a movement of the primary part 91 is accompanied by a pivot movement of the lever 78 about the rotational axle 79. The guide element 76 can thus be moved relative to the cage 71 by a suitable electrical control of the electric motor 90. Correspondingly, the position of the cage 71 relative to the guide surface 72', with which the guide element 76 is disposed in contact, can be moved. In particular it is possible to vary the spacing between the cage 71 and the guide surface 72' in controlled manner in the region by a suitable electrical controlling in drive of the electric motor 90.

A motor control (not illustrated) for the electric motor 90 is provided in the lift according to Figs. 4A and 4B, which controls, in dependence on signals of suitable sensors, the currents for supply of the primary part 91 and the secondary part 92 or the devices 93 and 93' with respect to, for example, their amplitude, frequency and phase position in order to influence the position of the guide element 76 relative to the cage 71 according to

predetermined criteria. For example, sensors can be provided which during travel of the lift cage along the guide surface 72' detect vibrations of the cage 71 which occur transversely to the direction of movement of the cage 71. These vibrations can be reduced or, in a given case, suppressed in that the motor control induces the electric motor 90, depending on signals of these sensors, to movements which lead to compensation for the vibrations of the cage 71.

The lift 70 according to Figs. 4A and 4B can be modified in various ways within the scope of the invention.

In one variant the electric motor can be so arranged with respect to the guide device 75 that the primary part 91 is stationary relative to the lift cage 71 and the secondary part 92 together with the guide element 75 is movable relative to the cage 71. Moreover, it is possible to dispense with one of the devices 93 and 93'. In addition, the primary part 91 can have several conductor tracks which can be supplied with current independently of one another in order to produce the travelling magnetic field by several currents. These currents can have several different phases. In this case the current supply for the primary part has to be designed to be multi-phase and the motor control for the electric motor 90 has to be suitably adapted in order to suitably control the currents, which flow through the respective conductor tracks of the primary part 91, with respect to their amplitude, frequency and phase. Furthermore, the support 95 for the devices 93 and 93' can be made of a soft magnetic material in order to concentrate a magnetic flux on the sides of the devices 93 and 93', which are remote from the primary part 91, in the support 95.

In a further variant of the lift 70 the cage 71 can be guided at several guide rails 72 (for example at two rails arranged parallel to one another) and several guide devices 75 can be fastened at the cage 71 in order to guide the cage 71 along the respective guide rails 72. Several guide devices 75 could also be fastened to the cage 71 for guidance of the cage 71 at a respective one of the guide rails 72, for example two guide devices 75 spaced in the longitudinal direction of the respective guide rail 72. The guide rails 72 can also have, additionally to the already described guide surface 72', further guide surfaces suitable for guidance of the cage 71 in the longitudinal direction of the respective guide rail 72. Each guide rail 72 could have, for example, two or three guide surfaces extending in the longitudinal direction of the guide rail 72, wherein respectively adjacent guide surfaces - referred to a cross-section of the respective guide rail 72 - are arranged at an angle of

less than 180° (for example 90°) relative to one another. Correspondingly, several guide devices 75 can be arranged at the cage 71 in such a manner that the cage 71 - as described in connection with Fig. 4A - is brought into contact with each of the guide surfaces by way of at least one guide element 76 (preferably by way of two guide elements 76), wherein the guide elements 76 are each movable with respect to the cage 71 and the springs 86 are each biased in such a manner that the guide elements 76 act by a finite force on the respective guide surfaces even when the cage 71 is moved along the guide rail 72 and this should be disposed under the influence of disturbing forces which are oriented transversely to the direction of movement of the cage 71 and can excite the cage into corresponding vibrations. The arrangement of the cage 71 with respect to all guide elements 76 can, as is described above in connection with Figs. 4A-B, be electronically controlled in variable manner by a corresponding number of electric motors 90. In order to render the cage 71 insensitive relative to vibrations transversely to the direction of movement thereof, all relevant degrees of freedom of the cage 71 with respect to oscillation can be detected in terms of measurement by sensors. For reduction in the vibrations a motor control can be provided which appropriately controls the electric motor 90 in drive and induces movements which leads to compensation for the vibrations. The number and arrangement of the guide devices 75 and the electric motors 90 can be selected in correspondence with the number of degrees of freedom with respect to vibration which are to be detected by the motor control.

Fig. 5A shows a lift 100 which comprises a cage 102 movable along a track. Fig. 5B illustrates the lift 100 in a section 5B-5B according to Fig. 5A.

A guide rail 103 is arranged at a wall 101 of a lift shaft. The cage is guided, in the case of movement along the track at the guide rail 103, by conventional guide means which are not, however, shown in Figs. 5A-B. An electric motor 110 constructed in accordance with the invention serves as drive for movement of the cage 102 along the guide rail 103. The electric motor 110 is conceived as a linear motor on the basis of the concepts explained in connection with the electric motors 10 and 20. The electric motor 110 comprises a primary part 111 for producing a travelling magnetic field and a secondary part 112 for providing a static magnetic field.

The primary part 111 and the secondary part 112 are arranged in such a manner that the primary part 111 and the secondary part 112 are movable relative to one another under an

effect of the travelling magnetic field. The primary part 111 is arranged in such a manner that the travelling magnetic field able to be generated by the primary part 111 travels parallel to the path of the cage. The primary part 111 extends along the entire length of the path of the cage 102. It is fastened to the guide rail 103. The primary part 111 is composed of several modules which are arranged in succession along the path of the cage and which each have a conductor track arranged on a substrate, wherein the conductor tracks of the different modules can be supplied with a current for the purpose of producing the travelling magnetic field. Each module can be constructed like, for example, the primary part 11 of the electric motor 10. The conductor tracks of the different modules can be connected in series and have a common current supply. The conductor tracks of the different modules can, however, also have a separate current supply. The latter offers the possibility of producing the travelling magnetic field - depending on the respective requirement - merely in individual part sections of the track of the cage 102.

The secondary part 112 has a shorter length in the direction of the path of the cage 102 than the primary part 111 and is fastened at the cage 102. In the present case a connecting element 109 is arranged between the secondary part 112 and a cage 102 in order to keep the secondary part 112 at a suitable spacing from the cage 102. The secondary part has - as a comparison with Figs. 1B, 2B and 4B indicates - substantially the same structure as the secondary parts of the electric motors 10, 20 and 90.

The secondary part 112 comprises two devices 113 and 113' which are constructed like the devices 13 and 13' and can be realised according to, for example, the layouts indicated in Figs. 3B-C. Correspondingly, the devices 113 and 113' each comprise a respective conductor track which is arranged on a substrate and which can be supplied with an electric current for the purpose of producing a static magnetic field. The respective substrates are plate-shaped and have flat surfaces. The devices 113 and 113' are arranged parallel to one and are fastened to a support 115, which - as shown in Fig. 5B - has a U-shaped cross-section, in such a manner that an air gap is formed between the devices 113 and 113'. Like the supports 15, 25 and 95, the support 115 can also be made of a soft magnetic material.

The secondary part 112 is arranged in such a manner that the primary part 111 projects into the air gap between the devices 113 and 113' of the secondary part 112 and is not brought into contact with the devices 113 and 113' when the cage 102 is moved along the

guide rail 103. The latter presupposes that the mentioned guide means for guidance of the cage 103 along the guide rail 103 ensure the requisite degree of precision and rigidity.

In operation the cage 102 can be moved or held at a predetermined position in that the conductor tracks of the primary part 111 and the secondary part 112 are suitably supplied with current. If the primary part 111 is controlled in drive in such a manner that it produces a travelling magnetic field, then the cage 102 is moved synchronously with the travelling magnetic field along the guide rail 103. If not only the primary part 111, but also the primary part 112 are supplied with a direct current, then the cage 102 can be held at a predetermined position. The motor 110 can be so designed that the force which the electric motor 110 exerts on the cage 102 in operation is sufficient to hold the cage without further assistance. In this case the lift 100 can be operated without support means for the cage 102 (i.e. without a cable or belt) and without a counterweight.

The lift 100 can be modified in numerous ways within the scope of the invention. Since the primary part 111 and the secondary part 112 - referred to the longitudinal direction of the guide rail 103 - have a significantly different length, the current supply for the conductor tracks of the primary part 111 and the secondary part 112 can also be constructed in such a manner that currents flow only in the regions of the primary part 111 and of the secondary part 112 in which the primary part 111 overlaps the secondary part 112. The energy consumption of the electric motor 110 can be reduced in this manner. In a further variant the lift 100 can be guided at several guide rails 103. The guide rails can be arranged at different sides of the cage 102. Correspondingly, the cage 102 can be driven by several electric motors 110. In the latter case the primary parts 111 of the different electric motors 110 can be arranged at the respective guide rails and the corresponding secondary parts 111 fastened at the cage 102, for example according to the concept illustrated in Figs. 5A and 5B.

According to a further variant of the lift 100 the electric motor 110 can be replaced in each instance by a different electric motor constructed in accordance with the invention, the primary part of which is arranged in stationary position with respect to the cage 103 and the secondary part of which is arranged in stationary position with respect to the path of the cage 103. In this case the respective secondary part extends along the entire length of the track. The length of the respective primary part along the track can, thereagainst, be shortened by comparison with the length of the corresponding secondary part.

Moreover, the mentioned electric motors and the cage can be guided by separate means along the path of the cage 102. In addition, modifications disclosed for the electric motors 10, 20 and 90 can be analogously transferred to the electric motor 110.

Patent Claims

1. Electric motor (10, 20, 90, 110), with a primary part (11, 21, 91, 111) for generating a travelling magnetic field and a secondary part (12, 22, 92, 112) for providing a static magnetic field, wherein the secondary part and the primary part are movable relative to one another under an effect of the travelling magnetic field, characterised in that the secondary part (12, 22, 92, 112) comprises a substrate (50) and a conductor track (60), which is applied to the substrate (50), in the form of a layer structure (13, 13', 23, 23', 93, 93', 113, 113') and that the conductor track (60) can be supplied with an electric current (I_s) for the purpose of generating the static magnetic field.
2. Electric motor according to claim 1, characterised in that the substrate (50) has a flat surface.
3. Electric motor according to one of claims 1 and 2, characterised in that it is constructed as a linear motor (10, 20, 90, 110).
4. Electric motor according to one of claims 1-3, characterised in that at least one section of the conductor track (60) has the form of a coil, wherein each coil comprises one or more windings.
5. Electric motor according to one of claims 1-4, characterised in that the conductor track (60) is composed of conductor track sections (61, 62) which are respectively formed in different layers of the layer structure (13, 13', 23, 23', 93, 93', 113, 113').
6. Electric motor according to one of claims 1-5, characterised in that a first part (61) of the conductor track (60) is formed at a first surface of the substrate (50) and a second part (62) of the conductor track (60) is formed at a second surface of the substrate (50), wherein an electrical connection (65) is produced between the first and the second part.
7. Electric motor according to claim 1-6, characterised in that several serially arranged sections of the conductor track (60) each have the form of a coil, wherein the coils are constructed in such a manner that in the case of a current flow (I_s) through the conductor track (60) adjacent coils respectively produce magnetic fields with different polarity (+, -).

8. Electric motor according to claim 7, characterised in that the conductor track (60) is arranged in such a manner that the static magnetic field at a surface of the secondary part (12) has several regions with a periodic reversal of the polarity (+, -) of the magnetic field along a direction (Z) in which the secondary part (12) is movable relative to the primary part (11).
9. Electric motor according to one of claims 1-8, characterised in that the primary part (11) comprises a conductor track (40) arranged on a substrate (30) and that this conductor track (40) can be supplied with an electric current ($I_p(t)$), the current intensity of which varies with time (t), for the purpose of generating the travelling magnetic field.
10. Electric motor according to one of claims 1-8, characterised in that the primary part comprises several conductor tracks arranged on a substrate that each of these conductor tracks is respectively supplied with an electric current, the current intensity of which varies with time, for the purpose of generating the travelling magnetic field.
11. Electric motor according to one of claims 1-10, characterised in that an air gap, which is bounded by a planar surface of the primary part and a planar surface of the secondary part, is formed between the primary part (11, 21, 91, 111) and the secondary part (12, 22, 92, 112).
12. Electric motor according to one of claims 1-11, characterised in that the layer structure (13, 13', 23, 23', 93, 93', 113, 113') of the secondary part (12, 22, 92, 112) is fastened to a support (15, 25, 95, 115) of a magnetic material, wherein the support (15, 25, 95, 115) is arranged on a side of the layer structure (13, 13', 23, 23', 93, 93', 113, 113') remote from the primary part (11, 21, 91, 111).
13. Lift (100) with an electric motor (110) according to one of claims 1-12, wherein the lift (100) comprises a cage (102) and the cage (102) is movable by means of the electric motor (110) along a path and wherein the primary part (11) is arranged to be stationary along the path and the secondary part (112) is arranged at the cage (102) or the secondary part is arranged to be stationary along the path and the primary part is arranged at the cage.

14. Lift according to claim 13, with means (103) for guiding the cage (102) along the track, wherein the primary part (111) and the secondary part (112) are so arranged at the means (103) that the primary part (111) and the secondary part (112) are guided at a spacing from one another when the cage (102) is moved along the path.
15. Lift (70) with an electric motor (90) according to one of claims 1-12, wherein the lift (70) comprises a cage (71), which is movable along at least one guide surface (72'), and a guide element (76), which is arranged at the cage (71) to be movable and which is brought into contact with the guide surface (72'), the guide element (76) being movable together with the electric motor (90) relative to the cage (71).
16. Lift according to claim 15, wherein the primary part (91) is arranged to be movable together with the guide element (76) and the secondary part (92) is arranged to be stationary with respect to the cage (71) or that the secondary part is arranged to be movable together with the guide element and the primary part is arranged to be stationary with respect to the cage.
17. Lift according to one of claims 15 and 16, with a control for the electric motor (90) for reducing of vibrations of the cage (71) during movement of the cage along the guide surface (72').