

Electromagnetic Drive Device

The invention concerns an electromagnetic drive device comprising a stator and a coil.

Such drive devices are used advantageously in Wire Bonders for the horizontal movement of the bondhead.

- 5 An electromagnetic drive device of the type named in the preamble of claim 1 is known from the Swiss patent specification CH 678 907. The drive device serves for example the horizontal movement of the bondhead of a Wire Bonder within a predetermined working range. The drive device has two stationary stators each of which is combined with a coil so that the bondhead which is rigidly connected to both coils can be moved within the working range. The forces produced by the drive device produce large
10 moments particularly in the edge areas of the working range which, on the one hand, strain the bearings of the bondhead and, on the other hand, cause undesirable oscillations of the bondhead.

The object of the invention is to propose an electromagnetic drive device for use on a Wire Bonder with which the above-mentioned disadvantages are eliminated.

- 15 The invention proposes an electromagnetic drive device which comprises a stator and a coil with which the coil is designed so that the force exerted by the stator on the coil is always directed towards or away from a point P located as close as possible to the centre of gravity of the working organ driven by the drive device.

In the following, embodiments of the invention are described in more detail based on the drawing.

- It is shown in: Fig. 1 an electromagnetic drive device according to the prior art,
20 Fig. 2 an electromagnetic drive device in accordance with the invention,
Fig. 3 a coil,
Fig. 4-8 other drive devices, and
Fig. 9 a further coil.
- 25 Fig. 1 shows a plan view of an electromagnetic drive device representing the prior art for the movement of a working organ 1 on a baseplate in a horizontal xy plane. The working organ 1 is for example the bondhead of a Wire Bonder. The drive device has a stationary stator 2 and a coil 3 contactlessly combined with the stator 2. The working organ 1 which slides on the baseplate is rigidly connected to the coil 3 via a support element 4. The drive device enables the computer-controlled movement of the
30 working organ 1 in x direction. A second drive device, not presented here, enables the computer-controlled movement of the working organ 1 in y direction. The coil 3 therefore has a transversal degree of freedom in y direction so that in the stator 2 it is moveable in y direction. When the working organ 1 moves in y direction, then its centre of gravity 5 moves with it in y direction. The coil 3 is wound in the conventional way, ie, the turns 6 run parallel to the y axis. The force K exerted by the stator 2 on the coil

3 is therefore always directed in x direction. In the exemplary position shown in Fig. 1, the force K is not directed towards the centre of gravity 5 of the working organ 4. In this way, the drive device exerts a moment on the working organ 4 which depends on the size of the distance D.

Fig. 2 shows a plan view of an electromagnetic drive device in accordance with the invention for the movement of the working organ 1 on the baseplate. The drive device also has the stationary stator 2 and the coil 3 contactlessly combined with the stator 2. The coil 3 has again a transversal degree of freedom in y direction so that it is moveable in y direction in the stator 2. The turns of the coil 3 are now no longer wound parallel to the y axis but are wound arc-like curved in relation to the centre of gravity 5 of the working organ 1. The force F exerted by the stator 2 on the coil 3 is therefore always directed towards or away from the centre of gravity 5 of the working organ regardless of the present position of the coil 3 relative to the stator 2, so that the drive device exerts no moment on the working organ 1. In other words: The direction of the force F depends on the y position of the coil 3 in relation to the stator 2.

The stator 2 is, in a generally known design, formed for example as an E-shaped or as a voice coil drive.

In Fig. 3 the coil 3 in accordance with the invention is shown in a perspective presentation. The coil 3 comprises a coil body 7 onto which the turns 6 are wound. The parts 6a of the turns 6 running parallel to the xy plane have an arc-like curved shape, while the parts 6b of the turns 6 running vertically to the xy plane are straight. In order that the forces F_i which the stator 2 exerts on each individual turn i are all directed in the same direction towards the centre of gravity 5 of the working organ 1 which is mechanically rigidly connected to the coil 3 (Fig. 2), the parts of the turns 6 running parallel to the baseplate are arranged along concentric arcs whereby on operation of the coil 3, the centre of the arc coincides with the centre of gravity 5 of the working organ 1.

Fig. 4 shows an electromagnetic drive device for the computer-controlled movement of the working organ 1 on the baseplate which has the first stator 2 and the first coil 3 contactlessly combined with the first stator 2 as well as a second stator 8 and a second coil 9 contactlessly combined with the second stator 8. The two coils 3, 9 are each rigidly connected to the working organ 1 sliding on the baseplate by means of a support element 4. The turns 6 of both coils 3, 9 are wound in a curved shape or at least approximately curved. A generally known angle bearing 10 is intended to guide the working organ 1. The angle bearing 10 ensures that the working organ 1 is always equally orientated in relation to the x axis and the y axis. The angle bearing 10 is preferably an air bearing preloaded with vacuum.

The force F_1 exerted by the first stator 2 on the first coil 3 acts upon that part of the turns 6 of coil 3 which is located within the magnetic field created by the stator 2 and is directed towards or away from a first point P_1 . The force F_2 exerted by the second stator 8 on the second coil 9 is similarly directed

towards or away from a second point P_2 . Ideally, the points P_1 , P_2 would coincide with the centre of gravity 5 of the working organ 1. However, in practice it can be that this is not the case. Nevertheless, a salient reduction of the moments exerted on the working organ 1 can be achieved in comparison with solutions with conventional, straight-wound coils when the points P_1 , P_2 are located close to the centre of gravity 5 of the working organ 1. Here, close means that the distances of the points P_1 , P_2 to the centre of gravity of the working organ 1 are small in comparison to the maximum movements of the working organ 1.

Because the forces F_1 and F_2 act almost on the centre of gravity 5 of the working organ 1, the torques exerted by them on the working organ 1 are significantly smaller than with the prior art. In this way, the strain on the angle bearing 10 is also reduced. Furthermore, the salient reduction in the torques has the result that the entire system has a lesser tendency to oscillate. With predetermined maximum load on the angle bearing 10, the forces F_1 and F_2 driving the working organ 1 can therefore be increased thereby achieving shorter movement times. In addition, waiting times following a movement phase which serve to allow oscillations stimulated by the movement to decay, can be shortened. The same advantages also result when, instead of the angle bearing 10, a table, free from play and moveable in x and y directions is used onto which the working organ 1 is secured.

For control of the currents flowing through the coils 3, 9 it must be taken into consideration that the forces F_1 or F_2 exerted by the stators 2, 8 on the two coils 3 and 9 are directed towards or away from the points P_1 or P_2 located in the vicinity of the centre of gravity 5 of the working organ 1, ie, the directions of the forces F_1 and F_2 are dependent on the actual position of the coils 3, 9. The force F_1 is therefore, except in a special position, not parallel to the x axis. Therefore, even with a movement only in x direction, both coils 3, 9 must be driven.

It has been found that the force F_1 within the permitted working range in the xy plane can be represented as:

$$F_1 = F_{1x} + F_{1y}(y(P_1)),$$

whereby F_{1x} signifies the component of the force F_1 in x direction, F_{1y} the component of the force F_1 in y direction and $y(P_1)$ the y coordinate of the point P_1 in relation to the baseplate. The absolute strength of the force F_1 is naturally dependent on the current which flows through the coil 3. The component F_{1y} is an almost linear function of the y coordinate of the point P_1 . The component F_{1x} however is constant.

Similar is valid for the force F_2 :

$$F_2 = F_{2x}(x(P_2)) + F_{2y},$$

The exact position of the working organ 1 is acquired via a measuring system, eg, via a cross grid scored directly into the baseplate. If the actual position of the working organ 1 is known in relation to the baseplate, then the actual position of the points P_1 and P_2 is also known. The directions of the forces F_1

and F_2 can therefore be determined as a function of the position of point P_1 or P_2 , respectively, of the working organ 1 by means of the above equations. In order to move the working organ 1 from a location A to a location B, the method proceeding according to the following steps has proved to be successful:

1. Determining the displacement vector Q which points from the actual position A of the working organ 1 to the new position B;
2. Determining the directions of the forces F_1 and F_2 based on the actual position A of the working organ 1 or the positions of points P_1 and P_2 derived from it, respectively;
3. Presentation of the displacement vector Q as the sum of two vectors Q_1 and Q_2 , whereby the first vector Q_1 points in the direction of the force F_1 and the second vector Q_2 points in the direction of the force F_2 ;
4. Applying a current I_1 or I_2 corresponding to the force F_1 or F_2 , respectively, to the two coils 3, 9 whereby the ratio of the currents I_1 and I_2 is dimensioned according to the ratio of the lengths of the vectors Q_1 and Q_2 ;
5. Acquiring the new position of the working organ 1 after a predetermined cycle time Δt ;
6. Redetermining the displacement vector Q and redetermining the directions of the forces F_1 and F_2 based on the meanwhile achieved position of the working organ 1;
7. Presentation of the displacement vector Q as the sum of two new vectors Q_1 and Q_2 , whereby the first vector Q_1 points in the direction of the newly determined force F_1 and the second vector Q_2 in the direction of the newly determined force F_2 ;
8. Applying a current corresponding to the vectors Q_1 and Q_2 to the two coils 3, 9;

Steps 5 – 8 are repeated until the working organ has reached the new position B. The cycle time Δt for a Wire Bonder for which the bondhead is carried by the working organ 1 amounts typically to several tens to hundreds of microseconds.

Fig. 5 shows a further coil 11 which has two windings 12, 13 which electrically can either be connected in series or controlled individually. For reasons of illustrative clarity, the drawing is only presented schematically and not drawn to scale. The turns of the winding 12 run parallel to the xz plane as with the conventional coil quoted in Fig. 1, whereby the direction z runs vertically to the xy plane. The turns of the winding 13 run parallel to the xy plane. If the coil 11 is located in the central position in relation to the stator 8 as shown in Fig. 5, then the parts of the turns of the winding 13 which run parallel to the y axis are located outside the stator 8 so that the stator 8 cannot exert a force on the coil 11 in x direction. If the coil 11 is located outside the central position in x direction as shown in Fig. 6, then some of the parts of the turns of the winding 13 which run parallel to the y axis are located within the stator 8 so that the stator 8 also exerts a force on the coil 11 in x direction. With increasing distance of the coil 11 from the central position, the number of relevant parts of the turns of the winding 13 within the stator 8 increases. As a result, the force active in x direction increases with increasing distance of the coil 11

from the central position so that the total force exerted by the stator 8 on the coil 11 is always directed towards or away from a predetermined point P_1 which moves with the coil 11.

Given the case that the windings 12 and 13 are operated electrically independently, then the direction of the force F exerted on the coil 11 can be varied under computer control taking the position of the coil 11 into account.

The arc-like wound coil 3 (Fig. 3), as opposed to the coil constructed with two windings, has the advantage of the reduced weight in relation to the efficiency.

A drive device for moving the working organ 1 in a horizontal xy plane can also be realized in the forms presented in figures 7 and 8 with which only the coil 3 has a transversal degree of freedom, namely a transversal degree of freedom in y direction. A coil 14 which has no transversal degree of freedom in x direction combined with the stator 8 serves as the drive in y direction. The coil 14 is rigidly connected to a first table 16 (Fig. 7) moveable only in y direction on the baseplate, or to a bearing element 17 (Fig. 8) formed as an air bearing via a bridge 15. The bridge 15 is guided by a guide element 19 arranged laterally next to the stator 8 so that the bearing element 17 is only moveable in y direction. Drive in x direction is provided by an electromagnetic device 20 formed from the stator 2 and the coil 3 with which the force F exerted by the stator 2 on the coil 3 always points approximately towards or away from the centre of gravity of the working organ 1. With the solution shown in Fig. 7, the coil 3 is connected to a second table 18 which supports the working organ 1. The table 18 bears on the first table 16 and is only moveable in x direction in relation to the first table 16. With the solution shown in Fig. 8, the coil 3 is connected to the working organ 1 via the support element 4 whereby the working organ 1 (and therefore also the coil 3) follows the movement of the bearing element 17 in y direction and can slide along the front surface 21 of the bearing element 17 in x direction. The coil 3 makes the same movements as the working organ 1 in y direction which is why it must have a transversal degree of freedom in y direction.

Fig. 9 shows a perspective view of a coil 3 with which the turns 6 are not curved but which are wound approximately arc shaped by means of straight sections 22. The curved part of the turns 6 can be formed by means of only two but also by means of a larger number of straight sections 22. The coil 3 shown has three straight sections 22. The width of the stator 2 is dimensioned so that in each position of the coil 3 at least two adjacent sections are each at least partly located within the stator. The upper and lower surfaces 7a or 7b of the coil body 7 which are parallel to the baseplate are preferably as thick as the turns 6 so that the slot in the stator can be kept as narrow as possible. For reasons of illustrative clarity, only one single layer of the turns is drawn in Fig. 9. After winding, the turns 6 are glued together, for example, with a glass fibre reinforced epoxy adhesive.



CLAIMS

1. Electromagnetic drive device for the movement of a working organ (1) in a plane, with a stator (2) and a coil (3) contactlessly combined with the stator (2), **characterized in that** the parts of the turns (6a) of the coil (3) running parallel to the plane are formed curved or approximately curved along
5 straight sections (22).
2. Drive device in accordance with Claim 1, **characterized in that** the turns (6a) of the coil (3) running parallel to the plane are arranged concentrically.
3. Electromagnetic drive device for the movement of a working organ (1) in a plane, with a stator (2) and a coil (11) contactlessly combined with the stator (2), **characterized in that** the coil (11) has two
10 windings (12, 13) and in that the parts of the turns of the windings (12, 13) running parallel to the plane run approximately orthogonally to each other.
4. Drive device in accordance with Claim 3, **characterized in that** the windings (12, 13) are electrically separated.
5. Wire Bonder with at least one drive device in accordance with one of the previous claims 1 to 4.