

METHOD FOR INFLUENCING THE MAGNETIC COUPLING BETWEEN TWO BODIES WHICH ARE AT A DISTANCE FROM ONE ANOTHER, AS WELL AS AN APPARATUS FOR CARRYING OUT THE METHOD

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TECHNICAL FIELD

The present invention relates to the field of influencing magnetic fields. It relates in particular to a method for influencing the magnetic coupling between two bodies which are at a distance from one another, according to the precharacterizing clause of Claim 1,
10 and to an apparatus for carrying out the method.

PRIOR ART

Diamagnetism is defined as a characteristic of a substance of displacing to a greater or lesser extent a magnetic field which passes through it from its interior, and of
15 attenuating the magnetic field. An ideal diamagnet is a superconductor of a first type, which completely displaces the magnetic field from its interior, with the exception of a narrow edge area. In the case of diamagnetic material, circulating currents are induced by the outer magnetic field at the atomic level on the basis of the proposed model, the magnetic field of which circulating currents opposes the outer magnetic field and
20 attenuates it. In the case of the superconductor of the first type, a zero-loss screen current is created in the edge area in the macroscopic dimension by the outer magnetic field, and its magnetic field results in there being no field in the interior of the superconductor.

Because of the field displacement, the magnetic coupling between two bodies can in principle be varied (attenuated) by a diamagnetic body, when the diamagnetic body is brought into the region of the magnetic coupling between the bodies. It is not possible to control this process, and in particular it is not possible to switch the field displacement on and off easily.

DESCRIPTION OF THE INVENTION

The object of the invention is to specify a method and an apparatus by means of which the magnetic coupling between two bodies can be influenced and controlled easily and specifically.

The object is achieved by the totality of the features of Claims 1 and 10. It is essential for the invention that a controllable field displacement apparatus which has a field displacement region is fitted between the two bodies, and that the magnetic field between the two bodies is displaced in a predetermined manner from the field displacement region of the field displacement apparatus by appropriately driving the field displacement apparatus. The field displacement apparatus in this case defines a spatial region in which there is a magnetic induction flux density $\underline{B}$ where $\text{div}\underline{B}=0$, and there is a vector potential $\underline{A}$ where $\text{rot}\underline{A}=0$ and $\underline{B}=0$ in its outer area.

One control possibility is to switch the field displacement apparatus on or off in order to influence the magnetic coupling between the two bodies. This results in a change between full field displacement and no field displacement, corresponding to a switching process for the magnetic coupling.

In order to achieve a periodically varying coupling, such as that which occurs for example in conjunction with induced alternating currents, the field displacement apparatus can be switched on and off periodically in order to influence the magnetic coupling between the two bodies.

- 5 However, it is also feasible to vary the strength of the field displacement of the field displacement apparatus in order to influence the magnetic coupling between the two bodies, in order to achieve a continuous change, such as that which occurs, for example, during sinusoidal processes.

10 In this case, at least one toroidal coil, which is intrinsically closed, is preferably used to produce the field displacement region. Furthermore, the vector potential can be influenced by a winding through which current flows and which runs within the at least one toroidal coil, in the direction of the axis of the toroidal coil.

The magnetic coupling to be influenced may exist between identical bodies or different bodies. At least one of the bodies may therefore be a permanent magnet, whose
15 magnetic field interacts with another body. In particular, both bodies may be permanent magnets, which attract or repel one another in the course of their interaction, depending on the polarity.

At least one of the bodies may, however, also be an electromagnetic coil which either has a current flowing through it itself and produces a magnetic field, or through which a
20 varying magnetic field flows, as an induction coil. In particular, both bodies may be electromagnetic coils.

In this case, a controller is preferably used in order to control the field displacement

apparatus.

One refinement of the field displacement apparatus according to the invention is characterized in that the field displacement apparatus has at least one toroidal coil whose inner magnetic field is closed in the form of a ring and whose outer magnetic
5 field disappears. In particular, a winding (31) to which current can be applied and which runs in the direction of the axis of the toroidal coil can be arranged within the at least one toroidal coil.

According to one preferred development of this refinement, a plurality of toroidal coils which are directly adjacent to one another on a plane are arranged concentrically one
10 inside the other.

A particularly uniform field displacement region can be produced in the field displacement apparatus if a plurality of toroidal coils which are each directly adjacent to one another on two planes which are arranged one above the other, are arranged concentrically one inside the other.

15 The toroidal coils or the winding are/is in this case preferably connected to an electrical power supply, which is itself controlled by a controller.

BRIEF EXPLANATION OF THE FIGURES

The invention will be explained in more detail in the following text using exemplary
20 embodiments and in conjunction with the drawing, in which:

Fig. 1 shows, in a highly simplified form, various steps (Figures 1a to 1d) for influencing the magnetic coupling between two permanent magnets, according to one exemplary embodiment of the method according to the invention;

Fig. 2 shows a section through a toroidal coil, as is part of a field displacement apparatus according to one exemplary embodiment of the invention;

Fig. 3 shows a cross section through one exemplary embodiment of the field displacement apparatus according to the invention, having concentric toroidal coils, which are operated alternately, on two planes which are located one above the other;

Fig. 4 shows an illustration, comparable to Figure 1, of an arrangement in which the coupling between a permanent magnet and an electromagnetic coil is influenced according to the invention;

Fig. 5 shows an illustration, comparable to Figure 4, of an arrangement in which the coupling between two electromagnetic coils is influenced according to the invention; and

Fig. 6 shows a section through a field displacement apparatus according to another exemplary embodiment of the invention, with a toroidal coil and an additional winding running around in it, in order to control the vector potential.

The invention relates to the manner in which phenomena and effects of diamagnetism can be produced in a fixed predetermined region in space (field displacement region) and how this diamagnetic spatial region which is produced by external currents (field displacement region) can be used for interaction of magnetic or electromagnetic fields which are constant or which vary over time, and which extend into this region from different external independent sources (for example external permanent magnets or electromagnets).

In particular, the proposal covers the control of the outer steady-state fluxes, and/or fluxes which vary over time, of the magnetic fields which originate from the external sources.

In order to produce the diamagnetic spatial region, a specific field displacement apparatus is proposed, specifically a diamagnetism generator (DMG in the following text), whose variables and parameters are annotated with the index D . Within the fixed predetermined spatial region, the DMG produces closed circulations of the magnetic flux density of a magnetic field $\underline{B}_D$ which is constant and/or varies over time, where $\text{div}\underline{B}_D=0$ (in the interior of the spatial region). Outside the fixed spatial region, a vector potential $\underline{A}_D$ is produced with the radial gradient ($\text{grad}\underline{A}_{r,D}$), where $\text{rot}\underline{A}_D=0$ and $\underline{B}_D=0$. The fixed interaction of these two regions acts like the phenomenon of diamagnetism in the relationships with other external fluxes of the magnetic and/or electromagnetic fields, which extend into this region from other external sources (for example permanent magnets or electromagnets).

By way of example, a circular solenoid (toroidal coil) which is supplied from an electrical power source can be used as a DMG, producing a circular, intrinsically closed, electromagnetic field $\underline{B}_D$ (the direction of the field $\underline{B}_D$ is along the axis of the circular

solenoid). An outer circular region of the vectorial potential $\underline{A}_D$ also exists, with the radial gradient ($\text{grad}\underline{A}_{r,D}$) and the parameters on this region $\underline{B}_D=0$, $\text{rot}\underline{A}_D = 0$. If the solenoid is supplied with direct current, then $d\underline{A}_D/dt = 0$. If, in contrast, the solenoid is supplied with alternating current, then $d\underline{A}_D/dt = A_{0,D} * K_D * f(v)$ where $A_{0,D}$ = the
 5 amplitude of the vectorial potential $\underline{A}_D$, $f(v)$ = a function of the frequency of the alternating current, and K_D = a correction coefficient, which takes account of the wave phenomenon forms of $\underline{A}_D$.

Figure 1 shows a highly simplified illustration of the principle of the method according to the invention in the form of various steps (figure elements). According to Figure 1a,
 10 the method is based on two bodies 10 and 12, which are at a distance from one another and are in this case, by way of example, in the form of permanent magnets, and which are magnetically coupled such that a region is formed between them with a magnetic induction flux density 11 which is not zero. In the present example, the opposite poles of the two permanent magnets face one another, as a result of which the magnetic
 15 interaction exerts an attraction force on the two bodies 10, 12.

Now, according to the invention, a controllable field displacement apparatus 13 is introduced into the region of the magnetic induction flux density 11 which is not zero and has a control input 14 (illustrated symbolically by an arrow) for external control (Figure 1b). In this case, the field displacement apparatus 13 is preferably positioned
 20 such that the action of the field displacement is a maximum on the magnetic coupling of the two bodies 10, 12.

When the field displacement apparatus 13 is now switched on (symbolized by the block arrow at the control input 14 in Figure 1c) the field displacement that this results in produces a different magnetic induction flux density 11', which results in

correspondingly different magnetic coupling between the bodies. When the field displacement apparatus 13 is switched off again (Figure 1d), the original state from Figure 1a is produced again.

Instead of the magnetic coupling between two permanent magnets, the field displacement apparatus 18 – as shown in Figures 4 and 5 – may, however, also be used to influence the magnetic coupling between a permanent magnet 12 and an electromagnetic coil 25 (Figure 4), or between two electromagnetic coils 25 and 26 (Figure 5), in which case the electromagnetic coils 25, 26 are either themselves used to produce a magnetic constant field or alternating field, or for induction of a current by variation of the injected magnetic field.

The central element of one exemplary embodiment of the field displacement apparatus 13 or 18 according to the invention is a toroidal coil 15 of the type shown in the form of a section in Figure 2, in the interior of which the coil current forms a magnetic induction flux 17, which is closed in the form of a ring, while there is no field in the outer area.

If, as shown in Figure 3, a plurality of toroidal coils 19,...,21 and 19',...,21' which are each directly adjacent to one another on two planes which are arranged one above the other are arranged concentrically one inside the other in order to form a field displacement apparatus 18, a (diamagnetically acting) field displacement region 22 is formed between the coil planes and has the effect shown in Figure 1c when the coils 19,...,21 and 19',...,21' are switched on. In this case, the toroidal coils 19,...,21 and 19',...,21' are operated alternately both within each plane and between the planes.

Influencing the magnetic coupling makes it possible not only to influence (switch) magnetic forces but also to control inductive processes which may be involved with the

production and processing of alternating currents.

Figure 6 shows another exemplary embodiment of a field displacement apparatus according to the invention, in an illustration comparable to Figure 2. The field displacement apparatus 30 in Figure 6 has a toroidal coil 32 which extends along a central (circular) axis 33 and through which a coil current 34 flows. The coil current 34 produces a magnetic field $\underline{B}_D$ in the field region, which is directed into the plane of the drawing on the left and out of the plane of the drawing on the right. An additional winding 31 is arranged along the axis 33 in the interior of the toroidal coil 32 (by way of example and without any restriction to generality, Figure 6 shows four turns), which produces an additional magnetic field $\underline{B}_V$ in a further field region 36, which is oriented parallel to the coil current 34 and at right angles to the magnetic field $\underline{B}_D$ of the toroidal coil 32.

The variable $\text{grad}\underline{A}_{r,D}$ is influenced by the additional winding 31. The vectorial potential $\underline{A}_{r,D}$ and the variable $\text{grad}\underline{A}_{r,D}$ are influenced by the interaction of the two fields $\underline{B}_V$ and $\underline{B}_D$, in which case it is possible to vary the current through the winding 31 to create an influence, without having to vary the coil current 34 in the toroidal coil 32. This results in additional possible ways to influence magnetic couplings by means of the diamagnetic field displacement region.

LIST OF REFERENCE SYMBOLS

	10,12	Permanent magnet
	11,11'	Magnetic induction flux density
	13,18,30	Field displacement apparatus (controllable)
5	14	Control input
	15	Toroidal coil
	16	Coil current
	17	Magnetic induction flux
	19,20,21	Toroidal coil
10	19',20',21'	Toroidal coil
	22	Field displacement region
	23	Electrical power supply
	24	Controller
	25,26	Electromagnetic coil
15	31	Winding
	32	Toroidal coil
	33	Axis (toroidal coil)
	34	Coil current
	35	Magnetic field (winding 31)
20	36,37	Field region

Patent Claims

1. Method for influencing the magnetic coupling between two bodies (10, 12; 25, 26), which are at a distance from one another, characterized in that a controllable field displacement apparatus (13, 18, 30) which has a field displacement region (22) is fitted between the two bodies (10, 12; 25, 26), and in that the magnetic field (11) between the two bodies (10, 12; 25, 26) is displaced in a predetermined manner from the field displacement region (22) of the field displacement apparatus (13, 18, 30) by appropriately driving the field displacement apparatus (13, 18, 30).
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2. Method according to Claim 1, characterized in that the field displacement apparatus (13, 18, 30) is switched on or off in order to influence the magnetic coupling between the two bodies (10, 12; 25, 26).
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3. Method according to Claim 1, characterized in that the field displacement apparatus (13, 18, 30) is switched on and off periodically in order to influence the magnetic coupling between the two bodies (10, 12; 25, 26).
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4. Method according to Claim 1, characterized in that the strength of the field displacement of the field displacement apparatus (13, 18, 30) is varied in order to influence the magnetic coupling between the two bodies (10, 12; 25, 26).
5. Method according to one of Claims 1 to 4, characterized in that at least one toroidal coil (15; 19, 20, 21, 19', 20', 21'; 32), which is intrinsically closed, is used to produce the field displacement region (22).
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6. Method according to Claim 5, characterized in that the vector potential ($\underline{A}_{r,D}$) is influenced by a winding (31) through which current flows and which runs within the at least one toroidal coil (32), in the direction of the axis (33) of the toroidal coil (32).
- 5 7. Method according to one of Claims 1 to 6, characterized in that at least one of the bodies (10, 12; 25, 26) is a permanent magnet (10, 12).
8. Method according to Claim 7, characterized in that both bodies (10, 12) are permanent magnets.
9. Method according to one of Claims 1 to 6, characterized in that at least one of the
10 bodies (10, 12; 25, 26) is an electromagnetic coil (25, 26).
10. Method according to Claim 9, characterized in that both bodies (25, 26) are electromagnetic coils.
11. Method according to one of Claims 1 to 10, characterized in that a controller (24) is used in order to control the field displacement apparatus (13, 18, 30).
- 15 12. Field displacement apparatus (13, 18, 30) for carrying out the method, characterized in that the field displacement apparatus (13, 18, 30) defines a spatial region in which there is a magnetic induction flux density $\underline{B}$ where $\text{div}\underline{B}=0$, and there is a vector potential $\underline{A}$ where $\text{rot}\underline{A}=0$ and $\underline{B}=0$ in its outer area.
- 20 13. Field displacement apparatus according to Claim 12, characterized in that the field displacement apparatus (13, 18, 30) has at least one toroidal coil (15; 19,...,21; 19',...,21'; 32) whose inner magnetic field is closed in the form of a ring and

whose outer magnetic field disappears.

14. Field displacement apparatus according to Claim 13, characterized in that a winding (31) to which current can be applied and which runs in the direction of the axis (33) of the toroidal coil (32) is arranged within the at least one toroidal coil (32).
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15. Field displacement apparatus according to Claim 13, characterized in that a plurality of toroidal coils (15; 19,...,21; 19',...,21') which are directly adjacent to one another on a plane are arranged concentrically one inside the other.
16. Field displacement apparatus according to Claim 15, characterized in that a plurality of toroidal coils (15; 19,...,21; 19',...,21') which are each directly adjacent to one another on two planes which are arranged one above the other, are arranged concentrically one inside the other.
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17. Field displacement apparatus according to one of Claims 12 to 16, characterized in that the toroidal coil or coils (15; 19,...,21; 19',...,21'; 32) or the winding (31) is (are) connected to an electrical power supply (23), which is itself controlled by a controller (24).
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