HU000032669T2

(19) **HU** (11) Lajstromszám: **E 032 669** (13) **T2**

MAGYARORSZÁG
Szellemi Tulajdon Nemzeti Hivatala

EURÓPAI SZABADALOM
SZÖVEGÉNEK FORDÍTÁSA

(21) Magyar ügyszám: **E 13 828904**
(22) A bejelentés napja: **2013. 12. 23.**

(96) Az európai bejelentés bejelentési száma:
EP 20130828904
(97) Az európai bejelentés közzétételi adatai:
EP 2936181 A1 **2014. 06. 26.**
(97) Az európai szabadalom megadásának meghirdetési adatai:
EP 2936181 B1 **2017. 02. 22.**

(51) Int. Cl.: ***G01R 33/04*** *(2006.01)*
B06B 1/08 *(2006.01)*
G01R 33/12 *(2006.01)*

(86) A nemzetközi (PCT) bejelentési szám:
PCT/AT 13/050263
(87) A nemzetközi közzétételi szám:
WO 14094029

(30) Elsőbbségi adatok:
506202012 **2012. 12. 21.** **AT**

(72) Feltaláló(k):
BORZ, Markus, A-4611 Buchkirchen (AT)
FÜREDER-KITZMÜLLER, Friedrich, A-4048 Puchenau (AT)
HASLMAYR, Michael, A-4048 Puchenau (AT)
SCHUSTER, Stefan, A-4470 Enns (AT)

(73) Jogosult(ak):
voestalpine Stahl GmbH, 4020 Linz (AT)

(74) Képviselő:
Danubia Szabadalmi és Jogi Iroda Kft.,
Budapest

(54) **Eljárás és berendezés egy lemezcsomag mágneses tulajdonságainak meghatározására**

SZTNH-100027232

Method and device for determining the magnetic characteristics of a lamination stack

The invention relates to a method and an apparatus for determining the magnetic properties of a lamination stack having a ferromagnetic core, comprising an excitation device which comprises a power supply unit and an electrical resonant circuit excited by the power supply unit, said resonant circuit comprising a capacitor and an excitation winding which is electrically connected to the capacitor and is provided on the core, and which excitation winding generates a magnetic flux in the core for a magnetic circuit, and comprising a measuring device which has a measuring winding provided on the core and magnetically coupled to the excitation winding.

In order to determine or measure the magnetic property of a bundle of laminations, it is known from the prior art (AT391522B) to produce an electromagnetic flux having an excitation coil mounted on a U-shaped yoke or on a core which closes into a magnetic circuit via the bundle of laminations. The excitation coil is thereby fed by an alternating current voltage source. By means of a measurement coil which is magnetically coupled to the excitation coil, which is likewise mounted on the core, the magnetic property of the bundle of laminations can now be deduced. If hysteresis losses are to be measured with this method or this device, a comparatively high electrical loss factor has been found disadvantageously in the power supply of the device in order to be able to detect the limits of the hysteresis curve. This is all the more true when it comes to measuring bundles of laminations for high-performance electrical machines with regard to their magnetic properties.

Furthermore, it is known in the case of eddy current sensors (DE1773501A) to connect a capacitor to the excitation coil in parallel in order to give the excitation device a different resonance characteristic than the measuring device. The resonance frequency of the oscillating circuit of the excitation winding and capacitor differs from the excitation frequency of the oscillator, which excites the oscillating circuit as a power supply to a forced oscillation. Disadvantageously, this device also leads to a comparatively high electrical loss factor in its power supply. Furthermore, eddy current sensors are not suitable for measuring hysteresis losses.

Other relevant publications are: JPH11101863, JPH06194436, JPH08278358, WO2011/012159 and JP2006090825.

Description of the Invention

It is therefore an object of the invention to modify a device of the type described in the introduction in a structurally simple manner in such a way that, with this energy-efficient bundle of laminations, which is suitable for absorbing comparatively high magnetic flux densities, their magnetic property can be measured in particular with regard to magnetic losses.

The object is solved by the invention in that the power supply unit excites the oscillating circuit to an oscillation with the resonance frequency of oscillating circuit.

If the power supply unit excites the oscillating circuit to an oscillate with the resonance frequency of the oscillating circuit, even bundles of laminations with a high saturation design can be measured extremely energy-efficiently also with regard to their hysteresis losses. Apart from ohmic power losses, the energy required for a comparatively high magnetic flux in the bundle of laminations can be held in the excitation device for driving the excitation coil, or can be temporarily stored in the capacitor. According to the invention, the positive and negative saturation values of the hysteresis curve or loop with a comparatively low total reactive power can thus be measured several times over the measurement winding. The device can therefore be distinguished in its comparatively low-cost operation. Furthermore, additional measures for reactive current compensation can be dispensed with, which can be used for a further cost reduction of the device.

In general, it is mentioned that the bundle of laminations can represent a stator, rotor or else another electrical component of an electrical machine. Bundle of laminations can be understood to mean insulating connected lamination parts or electrical laminations. For example, baking lacquer can be used for connecting the lamination parts to a bundle of laminations. In addition, it is generally mentioned that, under magnetic property of a bundle of laminations, the magnetic losses of the bundle of laminations can be understood in particular, which can be composed of eddy current losses and/or hysteresis losses.

The measurement on the bundle of laminations can be performed particularly energy-efficiently if the power supply excites the oscillating circuit to a free oscillation. After a charging of the oscillating circuit by the power supply, no further electrical energy has to be supplied to the excitation device, so that an independent measurement of the magnetic properties is possible. This can, inter alia, lead to a measurement which is particularly stable with regard to disturbances. Advantageously, the resonance circuit can be excited to a free oscillation during the entire measurement data acquisition.

If the power supply excites the oscillating circuit to a forced oscillation, the accuracy of the measuring method can be further increased by repeated measurements at maximum voltage amplitude of the excitation oscillation for generating the magnetic flux. The device can thereby measure the magnetic property of a bundle of laminations extremely reproducibly. In addition, with these repeated measurements with a resonance oscillation at the excitation coil, the possibility can emerge of further increasing the accuracy of the measurement data by using an error calculation, for example standard deviation. Advantageously, the oscillating circuit can be excited to a forced oscillation during the entire measurement data acquisition.

The measurement on the bundle of laminations can be performed particularly energy-efficiently if the power supply excites the oscillating circuit to a temporarily free and temporarily forced oscillation. After a charging of the oscillating circuit by the power supply, for example as result of the forced oscillation, no further electrical energy has to be supplied to the excitation device, so that an independent measurement of the magnetic properties is possible. This can, inter alia, lead to a measurement which is particularly stable with regard to disturbances. Advantageously, the oscillation circuit can be excited to such a mixed oscillation (forced and free oscillation) during the entire measurement data acquisition.

The amplitude of the oscillation for generating the electromagnetic flux can be kept to a maximum during the measurement even in the case of active losses in the resonance circuit in that the excitation frequency of the power supply coincides with the resonance frequency of the oscillating circuit. The electrical energy consumed as the active power of the oscillating circuit can be replaced by the power supply.

For a comparatively robust and energy-efficient device, the power supply may have an inverter which forms a oscillating circuit inverter with the oscillating circuit of the excitation device. In addition, the manufacturing costs of the device can be considerably reduced. An inexpensive device can thereby be provided.

Reliable measurement data acquisition can occur when the inverter impresses a voltage into the oscillating circuit.

The energy efficiency of the device can be further increased if the oscillating circuit inverter has a switching device that switches the inverter resonantly. This resonant switching, that is to say the zero voltage or current switching, can still further excite the resonance oscillation of the oscillating circuit and generate an increased magnetic flux without additional energy supply for the excitation device.

Constructive simplicity can be achieved if the oscillating circuit is designed as a series oscillating circuit.

In order to improve the signal of the electrical variables measured by the oscillating circuit, the oscillating circuit can have a throttle.

If the oscillating circuit has at least one capacitance that can be changed in size to change its resonance frequency f_{res}, an increased power spectrum of the bundle of laminations can be measured with respect to magnetic losses. A bandwidth of the resonance frequency of 50 Hz to 10 kHz can be found to be advantageous here. With a low resonance frequency, for example, hysteresis losses can be predominantly detected, for which purpose higher resonance frequencies can be suitable for detecting the eddy current losses.

The oscillating circuit can be provided with a capacitance element, which can be switched on and off by means of a switch in order to change its resonance frequency f_{res}. Needless to say in gerneral, capacitance elements can, for example, be capacitors.

The object of the invention is also to provide a method for determining the magnetic property, in particular with regard to the magnetic losses, of a bundle of laminations, which is extremely energy-efficient.

The object is solved by the invention in that the oscillating circuit for generating the electromagnetic flux is excited to an oscillation with its resonance frequency.

If the oscillating circuit for generating the electromagnetic flux is excited to an oscillation with its resonance frequency, a particularly energy-efficient method can be made to determine the saturation values of a bundle of laminations so as to determine the magnetic losses, preferably hysteresis losses, and consequently the maximum losses.

Simple method conditions are obtained by exciting the oscillating circuit to a free oscillation. It can indeed be sufficient to use a free swing-out behaviour of the oscillating circuit for a sufficient measurement data acquisition. Advantageously, the resonance circuit can be excited to a free oscillation during the entire measurement data acquisition.

The accuracy of the measurement data acquisition for determining saturation values of the bundle of laminations can be increased by exciting the oscillating circuit to a forced oscillation. Due to the increased number of identical oscillations acquired through repeated measuring, the option to use methods for error correction can be adopted in order to further increase the accuracy of the method. Advantageously, the oscillating circuit can be excited to such a mixed oscillation (forced and free oscillation) during the entire measurement data acquisition.

Simple and yet energy-efficient method conditions are obtained by exciting the oscillating circuit to a temporarily free and temporarily forced oscillation. On the basis of the measured data for free oscillation, a free swing-out behaviour of the oscillating circuit can be measured, for example, which can contribute to a high accuracy in the determination of the magnetic losses. Advantageously, the oscillating circuit can be excited to a forced and free oscillation during the entire measurement data acquisition.

The method can be further improved with respect to its accuracy in the determination of saturation values of the bundle of laminations in that the excitation frequency and the resonance frequency of the oscillating circuit are identical. In this way, it is possible to provide an increased number of redundant measurement data for determining the magnetic property of the bundle of laminations.

If the resonance frequency of the oscillating circuit is changed for the determination of the magnetic property of the bundle of laminations, an increased power spectrum of the bundle of laminations can be measured with respect to the magnetic losses. A bandwidth of the resonance frequency of 50 Hz to 10 kHz can be found to be advantageous here. With a low resonance frequency, for example, hysteresis losses can be predominantly detected, for which purpose higher resonance frequencies can be suitable for detecting the eddy current losses.

Simplified handling conditions for the method can result in the size of the capacitance being changed. This change can be effected, for example, by changing the size of the electrical capacitance in the oscillating circuit by switching on or switching off capacitances via switches to the oscillating circuit.

in the determination of the magnetic property of the bundle of laminations, it is possible to distinguish between eddy current losses and hysteresis losses, in which the oscillating circuit is operated successively with two different resonance frequencies. A bandwidth of the resonance frequency of 50 Hz to 10 kHz can be found to be advantageous here. With a low resonance frequency, for example, hysteresis losses can be predominantly detected, for which purpose higher resonance frequencies can be suitable for detecting the eddy current losses.

The method can be improved if a mathematical model of the hysteresis curve, which is taken into account in the determination of the magnetic property of the bundle of laminations, is determined based on the recorded measurement data. The area of the hysteresis curve can represent a measure of the magnetic losses. Various methods can be used to determine a mathematical model of the hysteresis curve. For example, a Langevin function can be used to mathematically describe the hysteresis with a parametric model. The parameters for this function can be determined from the current measured data or estimated from it. Other functions are generally conceivable.

If, in the mathematical model, the air gap is taken into account as a shear of the hysteresis curve, the method can improve in accuracy. For small air gaps, it is possible to assume that the air gap shears the hysteresis curve with a straight line. If the air gap is taken into account in the mathematical model, the influence of the air gap and the influence of the bundle of laminations can be distinguished.

The accuracy of the method can be further increased if, during the determination of the magnetic properties of the bundle of laminations, a comparison is made between reference measurement data on a reference bundle of laminations with the recorded measurement data. For this purpose, a measuring bridge can be advantageously used.

Brief Description of the Drawing

The object of the invention is, for example, shown in more detail in the figures with reference to exemplary embodiments.

Fig. 1 shows a schematic view of a device according to the invention for measuring a magnetic property of a bundle of laminations according to a first exemplary embodiment,

Fig. 2 shows a schematic view of an alternative embodiment of an excitation device alternative to Fig. 1 according to a second exemplary embodiment,

Fig. 3 shows the oscillating circuit of Fig. 2 with a detailed view of the capacitance,

Fig. 4 shows a signal path for free oscillation,

Fig. 5 shows a signal path for forced oscillation,

Fig. 6 shows a signal path for a temporarily free and temporally forced oscillation and

Fig. 7 shows a schematic view of a further excitation device alternative to Fig. 1 according to a third exemplary embodiment.

Way of implementing the invention

The device 1 according to a first exemplary embodiment shown in Figure 1 for measuring magnetic losses, for example using the hysteresis curve 2, of a bundle of laminations 3, has a ferromagnetic core 4. Around this core 4, two windings are provided, namely an excitation winding 5 and a measurement winding 6, which are magnetically coupled. The excitation winding 5 is part of an excitation device 7, which includes a power supply 8 and a capacitance 9. The excitation device 7 and capacitance 9 are electrically connected to a series oscillating circuit 10. This capacitance 9 can, for example, be formed by one or more interconnected capacitance elements, for example capacitor or capacitors.

The electrical power supply 8 is shown according to Fig. 1 as a current source 11 controllable via a control voltage and generates a current $i_e(t)$ in the oscillating circuit 10, as a result of which the excitation winding 5 generates a magnetic flux 12 in the core 4 which leads to a magnetic circuit 13. In this magnetic circuit 13 lie the bundle of laminations 3, the core 4 and the air gaps resulting between the core 4 and the bundle of laminations 3. The magnetic circuit 13 therefore passes over the bundle of laminations 3.

The measurement winding 6 is part of a measurement device 14 which is magnetically coupled to the excitation winding 5. Preferably, the excitation device 7 and measurement winding 6 have different winding numbers. The measuring voltage $u_m(t)$ is picked up by the measurement winding 6, which is designed as a coil, by a voltage measurement device 15, which voltage $u_m(t)$ is taken into account during the determination of the magnetic property of the bundle of laminations 3. In order to generate high flux densities in the bundle of laminations 3 while nevertheless being able to achieve a particularly high energy efficiency, the oscillating circuit 10 is excited by the power supply 8 with the resonance frequency f_{res} of the oscillating circuit 10.

As shown in Figures 4, 5 and 6, the oscillating circuit 10 can oscillate differently with the resonance frequency f_{res}.

For example, an oscillating circuit 10 is excited to a free oscillation 16 with the resonance frequency $fres=1/\sqrt{LC}$ of the oscillation circuit 10, with such an oscillation 16 according to Fig. 4 able to be seen. This undergoes an attenuation by the oscillation 16 by the electrical resistors, not shown in detail. To realise this excitation, reference is made to an excitation device 17 of Fig. 7, which is an alternative embodiment to the exciter device 7 shown in Fig. 1, whereby a second exemplary embodiment is formed. Thus seen from Fig. 7 is a voltage source 22, which can be switched on and off via a change-over switch 28, which is used to charge the capacitance 9 and thus to excite the oscillating circuit 10 to a free attenuated oscillation 16 according to Fig. 4.

As an alternative to Fig. 7, in Fig. 5 the oscillating circuit 10 is excited with a forced oscillation 23 by means of the voltage u(t), which leads to an excitation current $i_e(t)$. Advantageously, the excitation frequency f coincides with the resonance frequency $fres = 1/\sqrt{LC}$ of the oscillating circuit 10. Thus, the attenuation of the oscillating circuit 10 caused by active power can be compensated for, and an electromagnetic flux 12 with a high flux density can always be generated. As can be seen here, this oscillation 23 can keep the amplitude in the oscillating circuit, despite the active loss. This significantly increases the accuracy of the method for determining the magnetic property of the bundle of laminations 3.

If the excitation frequency f is selected to be so long that a free attenuated oscillation 16 adjusts with the resonance frequency, $fres = 1/\sqrt{LC}$ the resonance circuit 10 can also be excited with a combination of temporarily forced oscillation 23 and temporarily freely attenuated oscillation 16. Fig. 6 shows the oscillating circuit 10 to be temporarily supplied with an excitation u(t) before a free oscillation 16 is permitted. Furthermore, by means of this previous excitation with a forced oscillation 23, the capacitance 9 for the free oscillation 16 is sufficiently charged, which makes the method particularly fast and easy to handle. For this purpose, for example, the excitation device 24 shown in Fig. 2 can be used.

This excitation device 24 according to Fig. 2 also has a particularly robust design of the electrical source for the power supply 8 of the oscillating circuit 10. Here, an inverter 18, which forms a oscillating circuit inverter 19 with the oscillating circuit 10, is used. The inverter 18 impresses an alternating voltage u(t) into the oscillating circuit 10, which leads to an excitation current $i_e(t)$. In addition, the inverter 18 is controlled to be resonant within the meaning of a zero-voltage switching, in that a switching device 20 actuates the respective switches 21 in the event of a zero crossing of the load voltage.

The oscillating circuit 10 of Fig. 2, which is shown in greater detail in Fig. 3, shows a capacitance element 91 which can be switched on and off in its capacity 9. The switch 27 is actuated for this purpose. It is also possible to provide a plurality of capacitances 91 which can be switched on and off - which are not shown in detail. With the capacitance element 91, which can be switched on and off, the resonance frequency f_{res} of the oscillating circuit 10 can be adjusted in accordance with the measurement requirement, since the capacitance 9 can thereby be resized according to the capacitance element 90 and the capacitance element 91. Thus, an increased performance spectrum of the bundle of laminations 3 can be measured with respect to magnetic losses. A bandwidth of the resonance frequency of 50 Hz to 10 kHz is advantageous here. With a low resonance frequency, hysteresis losses can be detected predominantly, whereby a higher resonance frequency is suitable for the predominant detection of eddy current losses. The oscillating circuit 10 shown in Fig. 3 also offers the same function.

The throttle 25 in the resonance circuit 10 is used to improve the signal $i_e(t)$.

As can be seen from Fig. 1, the excitation current $i_e(t)$ for measuring the magnetic property of the bundle of laminations 3 is also used for the measurement voltage $u_m(t)$ tapped by the measurement winding 6 designed as a measurement coil. This makes it possible to illustrate the hysteresis curve 2 in order to determine the magnetic property of the bundle of laminations 3. For this purpose, the magnetic flux is determined by an integrator 26 from the measuring voltage by $u_m(t)$, whereby the magnetic flux density B can be determined. The excitation current $i_e(t)$ is used to determine the magnetic field strength H so that the hysteresis curve can be plotted by knowing H and B. For an increased sensitivity, the ratio of the air gap to the effective magnetic path is kept low.

Based on the recorded measurement data, it is also possible to determine a mathematical model of the hysteresis curve 2, as indicated in Fig. 1. The area of the hysteresis curve 2 can represent a measure of the magnetic losses. Various methods can be used to determine a mathematical model of the hysteresis curve 2. For example, a Langevin function can be used to mathematically describe the hysteresis with a parametric model. The parameters for this function can be determined from the current measured data or estimated from it. In the mathematical model, the air gap is taken into account as a shear of the hysteresis curve 2, which increases the method in terms of accuracy. A comparison between reference measurement data on a reference bundle of laminations (not shown) with the measurement data recorded by the bundle of laminations 3 under test can further increase this accuracy. For this purpose, a measuring bridge (not shown) can be used.

Eljárás és berendezés egy lemezcsomag mágneses tulajdonságainak meghatározására

Szabadalmi igénypontok

1. Berendezés egy olyan lemezcsomag (3) mágneses tulajdonságainak meghatározására, amelynek ferromágneses magja (4), gerjesztő-berendezése (7, 17, 24) van, amely tápforrással (8) és egy a tápforrás (8) által gerjesztett villamos rezgőkörrel (10) rendelkezik, amely kapacitást (9) és egy a kapacitással (9) villamosan összekötött, a magon (4) elhelyezett gerjesztőtekercset (5) tartalmaz, mely gerjesztőtekercs (5) arra van kialakítva, hogy egy mágneses körhöz (13) mágneses fluxust (12) hozzon létre a magban (4), és tartalmaz továbbá egy mérőberendezést (14), amelynek a magon (4) elrendezett, a gerjesztőtekerccsel (5) mágnesesen csatolt mérőtekercse (6) van, ahol a tápforrás (8) úgy van kiképezve, hogy a rezgőkört (10) rezgésre (23) késztesse a rezgőkör (10) rezonancia frekvenciájával (f_{res}),

azzal jellemezve, hogy a tápforrás (8) egy váltóirányítóval (18) rendelkezik, amely a gerjesztő-berendezés (7) rezgőkörével (10) egy rezgőkörös váltóirányítót (19) képez.

2. Az 1. igénypont szerinti berendezés, azzal jellemezve, hogy a tápforrás (8) a rezgőkört (10) szabadrezgésre (16) gerjeszti.

SZTNH-100027233

3. Az 1. igénypont szerinti berendezés, azzal jellemezve, hogy a tápforrás (8) a rezgőkört (10) vagy kényszerrezgésre (23) vagy időnként szabadrezgésre és időnként kényszerrezgésre (16, 23) gerjeszti.

4. A 3. igénypont szerinti berendezés, azzal jellemezve, hogy a tápforrás (8) gerjesztő-frekvenciája (f) megegyezik a rezgőkör (10) rezonancia frekvenciájával (f_{res}).

5. Az 1-4. igénypontok bármelyike szerinti berendezés, azzal jellemezve, hogy a rezgőkörös váltóirányítónak olyan kapcsolókészüléke (20) van, amely a váltóirányítót (18) rezonanciával kapcsolja.

6. Az 1-5. igénypontok bármelyike szerinti berendezés, azzal jellemezve, hogy a rezgőkörnek (10) a jel javításához fojtótekercse (25) van.

7. Az 1-6. igénypontok bármelyike szerinti berendezés, azzal jellemezve, hogy a rezgőkör (10) rezonancia frekvenciája (f_{res}) változtatásához legalább egy, értékében változtatható kapacitást (9) tartalmaz.

8. A 7. igénypont szerinti berendezés, azzal jellemezve, hogy a rezgőkörnek (10) egy kapcsolóval (27) hozzákapcsolható és lekapcsolható kapacitás eleme (91) van.

9. Eljárás egy lemezcsomag mágneses tulajdonságának meghatározására, amelynek során egy, egy magon (4) elrendezett gerjesztőtekerccsel (5) elektromágneses fluxust (12) hozunk létre, amennyiben egy olyan rezgőkört (10), amely gerjesztőtekercset (5) és egy kapacitást (9) foglal magában, egy tápforrással (8) rezgésre (16, 23) gerjesztünk, a létrehozott mágneses fluxus (12) mágneses kört (13) alakít ki a lemezcsomagon (3) és a magon (4) keresztül, és egy a gerjesztőtekerccsel (5) mágnesesen csatolt mérőtekercs (6) segítségével mérési adatokat veszünk fel és legalább ezen mérési adatok alapján a lemezcsomag (3) mágneses tulajdonságait meghatározzuk, azzal jellemezve, hogy a rezgőkört (10) az elektromágneses fluxus (12) létrehozásához saját rezonancia frekvenciájával (f_{res}) rezgésre (23) gerjesztjük, amelyhez a tápforrás (8) váltóirányítót (18) tartalmaz, amely a gerjesztő-berendezés (7) rezgőkörével (10) rezgőkörös váltóirányítót (19) képez.

10. A 9. igénypont szerinti eljárás, azzal jellemezve, hogy a rezgőkört (10) szabadrezgésre (16) gerjesztjük.

11. A 9. igénypont szerinti eljárás, azzal jellemezve, hogy a rezgőkört (10) vagy kényszerrezgésre (23), vagy időnként szabadrezgésre és időnként kényszerrezgésre (16, 23) gerjesztjük.

12. A 11. igénypont szerinti eljárás, azzal jellemezve, hogy a gerjesztő frekvencia (f) és a rezgőkör (10) rezonancia frekvenciája (f_{res}) egymással egyező.

13. A 9-12. igénypontok bármelyike szerinti eljárás, azzal jellemezve, hogy a lemezcsomag (3) mágneses tulajdonságának meghatározása során a rezgőkör (10) rezonancia frekvenciáját (f_{res}), különösen a kapacitás (9) értékén keresztül, változtatjuk.

14. A 13. igénypont szerinti eljárás, azzal jellemezve, hogy a lemezcsomag (3) mágneses tulajdonságai esetében örvényáramú veszteségeket és hiszterézis veszteségeket különböztetünk meg, amennyiben a rezgőkört (10) egymás után két különböző rezonancia frekvenciával (f_{res}) működtetjük.

15. A 9-14. igénypontok bármelyike szerinti eljárás, azzal jellemezve, hogy a felvett mérési adatok alapján meghatározzuk a hiszterézis görbe (2) matematikai modelljét, amelyet a lemezcsomag (3) mágneses tulajdonságának meghatározása során figyelembe veszünk.

16. A 15. igénypont szerinti eljárás, azzal jellemezve, hogy a matematikai modell esetében a légrést a hiszterézis görbe (2) elnyíródásaként vesszük figyelembe.

17. A 9-16. igénypontok bármelyike szerinti eljárás, azzal jellemezve, hogy a lemezcsomag (3) mágneses tulajdonságainak meghatározása során összehasonlítást végzünk egy referencia lemezcsomagon mért referencia mérési adatok és a felvett mérési adatok között.

18. A 9-17. igénypontok bármelyike szerinti eljárás, azzal jellemezve, hogy a rezgőkörös váltóirányítónak (19) kapcsolókészüléke (20) van, amely a váltóirányítót (18) rezonanciában kapcsolja.

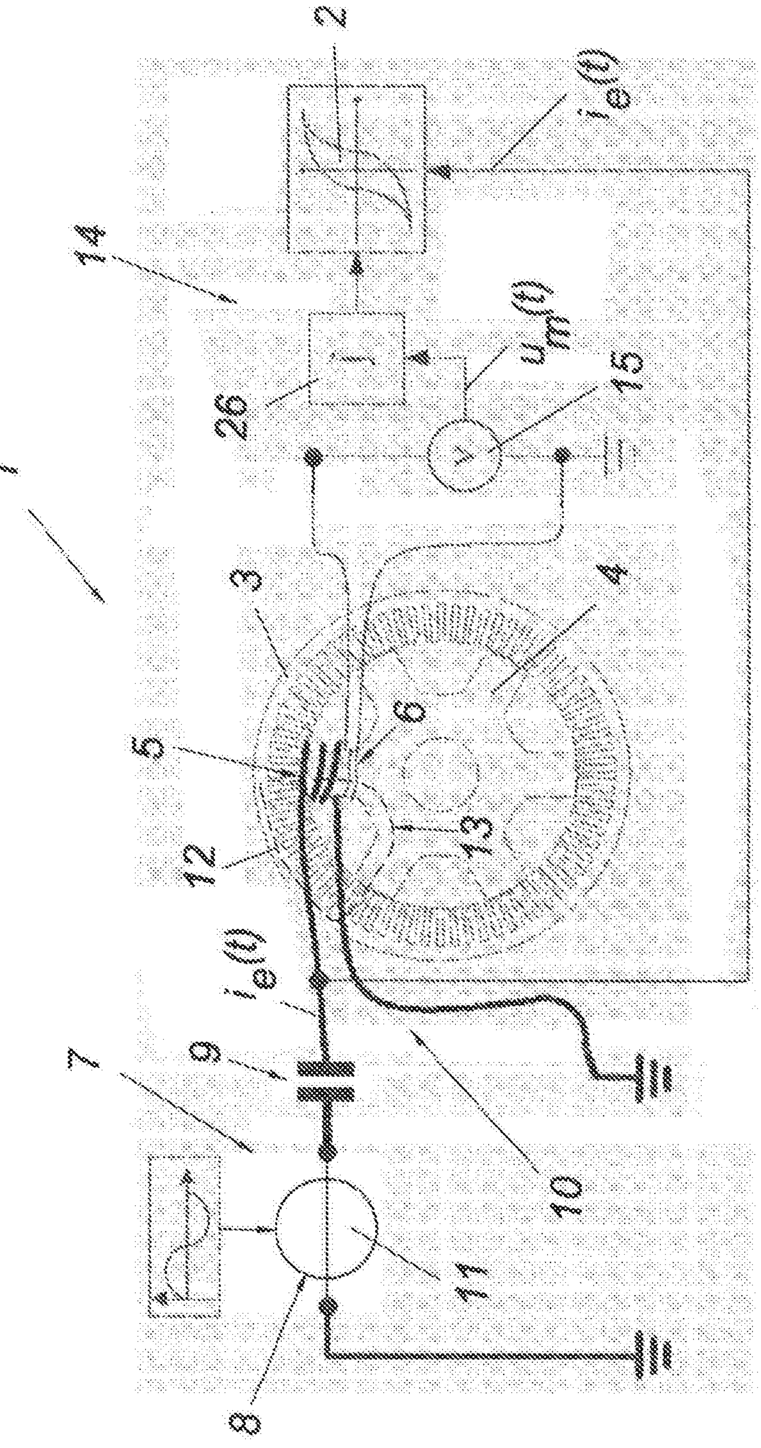

FIG.1

FIG.2

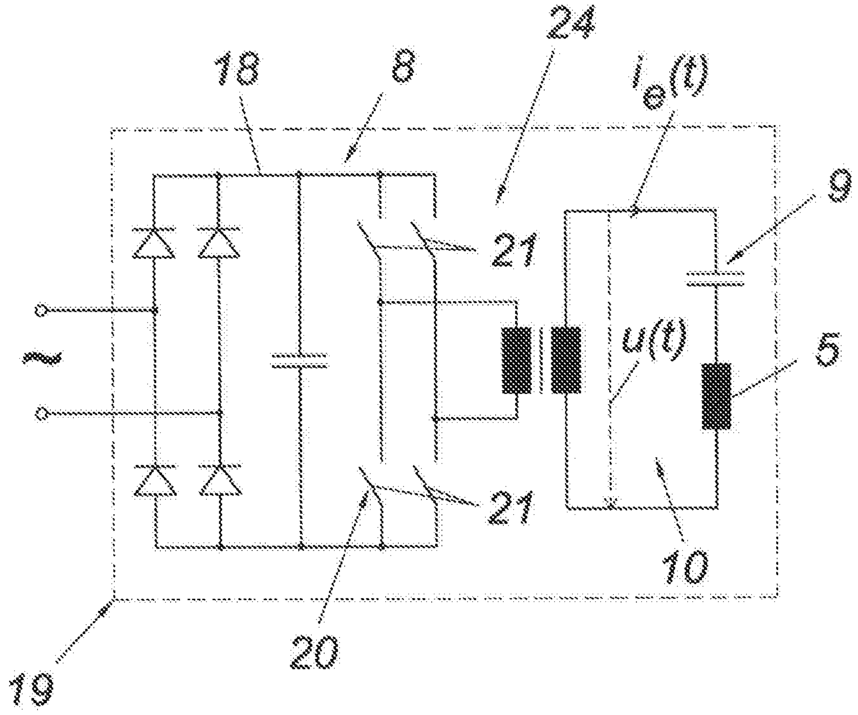

FIG.3

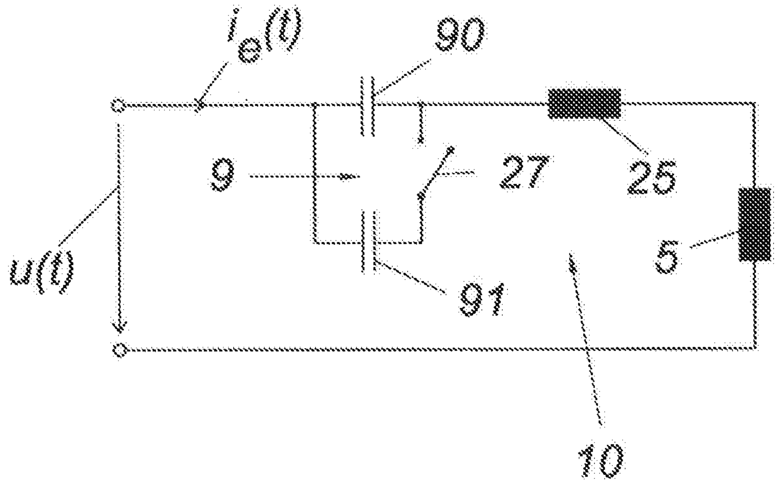

FIG.4

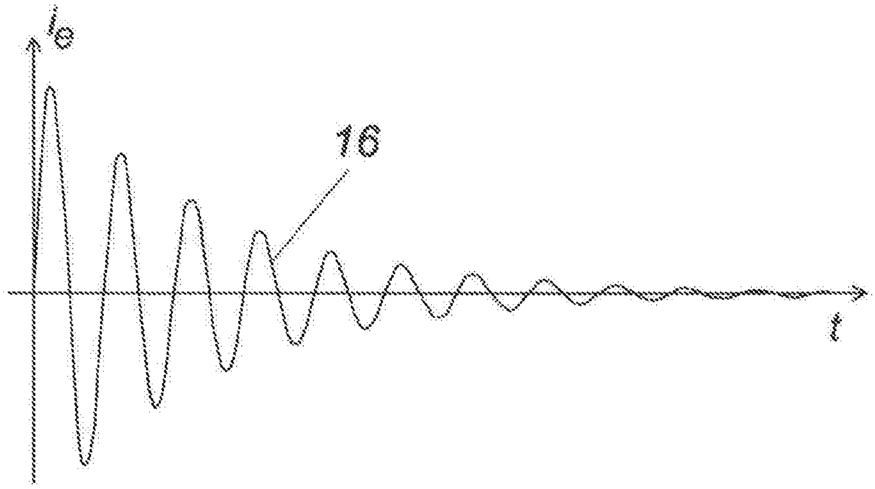

FIG.5

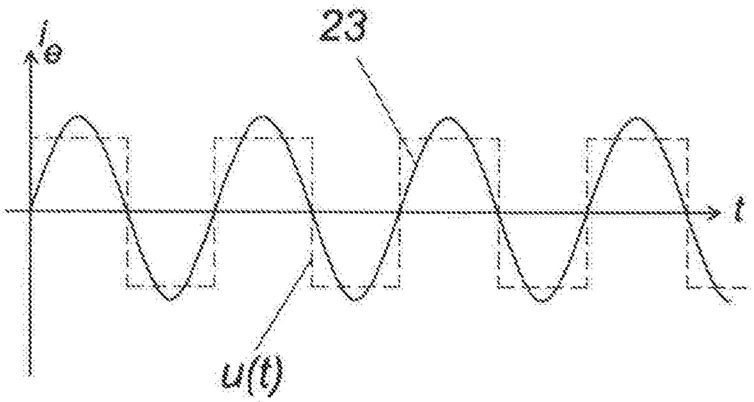

FIG.6

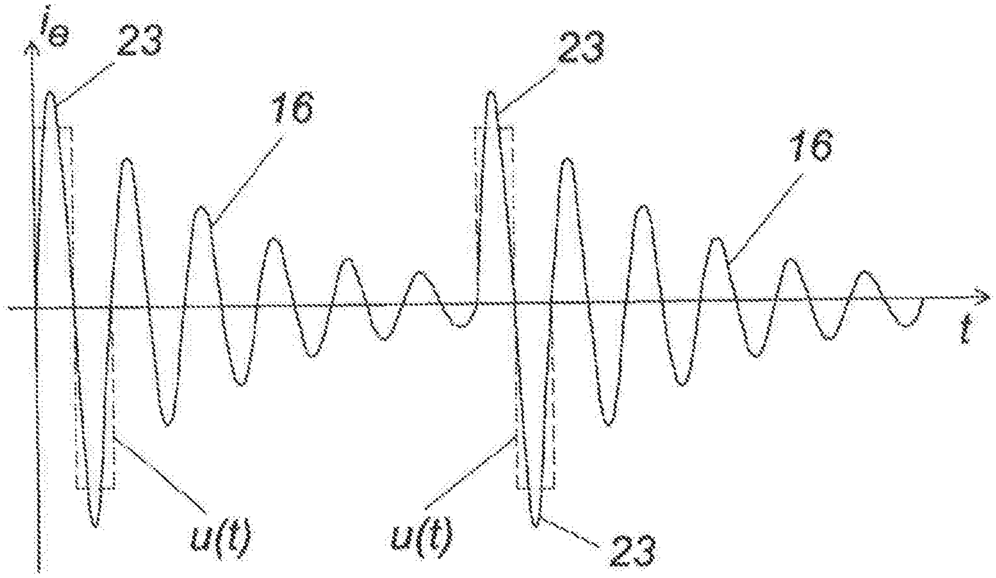

FIG.7