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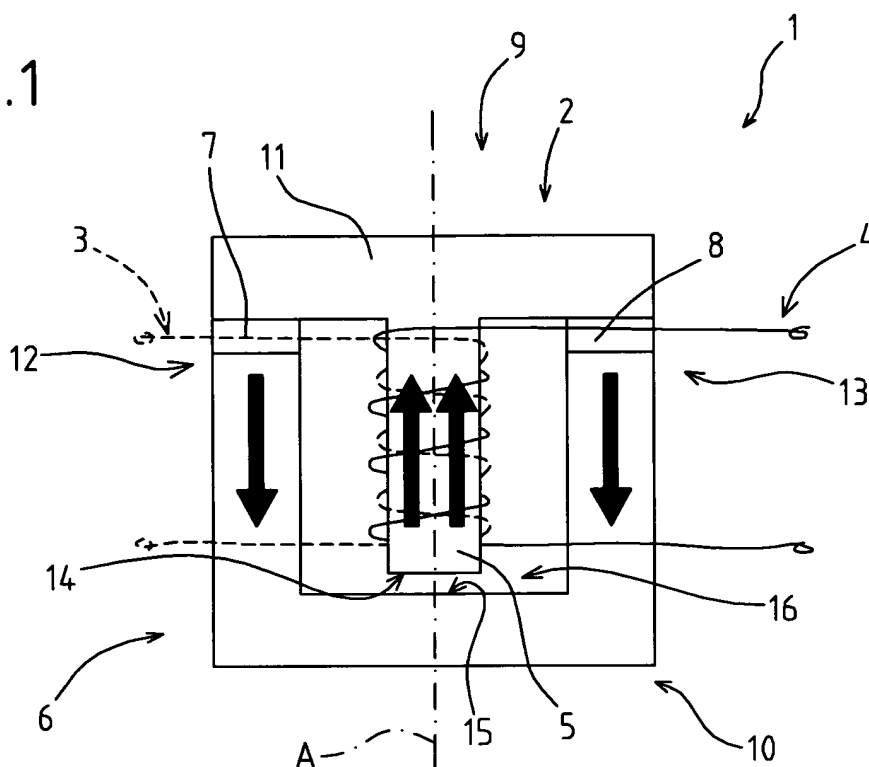
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(54) **Ignition coil**

(57) An ignition coil (1; 20) for triggering combustion in a controlled ignition endothermic engine has: a magnetic circuit (2; 21) having a core (5; 24), a cladding (6; 25), a first permanent magnet (7; 26) and a second per-

manent magnet (8; 27) set in parallel along the cladding (6; 25); a primary electrical circuit (3; 22) wound around the core (5; 24); and a secondary electrical circuit (4; 23) wound around the core (5; 24) and concatenated with the primary electrical circuit (3; 22).

Fig.1



Description

[0001] The present invention relates to an ignition coil. In particular, the present invention regards an ignition coil for triggering combustion in a controlled ignition endothermic engine.

[0002] A known type of ignition coil comprises: a magnetic circuit including a core, a cladding, and a permanent magnet; a primary electrical circuit wound around the core; and a secondary electrical circuit wound around the core and concatenated with the primary electrical circuit.

[0003] The core extends principally along one axis, and the cladding extends along an annular closed path about the core and lies substantially in the same plane as the axis of the core.

[0004] The permanent magnet (also referred to as "preload magnet") is set along the core and enables variations of magnetic induction in the magnetic circuit of the ignition coil that are greater than the variations of magnetic induction that can be obtained in a magnetic circuit without permanent magnet. For example, with reference to the known characteristic curve B-H that links the magnetic induction B with the magnetizing force H of the magnetic circuit, the permanent magnet displaces the point of rest (at zero current) of the curve so as to enable wide variations of magnetic induction in the linear stretch of the characteristic curve B-H.

[0005] However, ignition coils of this type present problems linked to the dimensions of the permanent magnet itself and hence impose limits on the lowering of the point of rest of the curve. In fact, the presence of a permanent magnet contributes to the generation of the magnetic field and, at the same time, constitutes an important source of reluctance. To a first approximation, the cross section of the permanent magnet, understood as the cross section substantially orthogonal to the flux lines of the magnetic field, is correlated to the capacity of magnetization of the permanent magnet itself, whilst the thickness of the permanent magnet, understood as the length of the permanent magnet in the direction of the flux lines of the magnetic field, is correlated to its equivalent reluctance.

[0006] Consequently, the optimal solution from the theoretical standpoint would consist in producing a thin permanent magnet provided with a relatively extensive cross section. However, a relatively thin permanent magnet is subject to frequent breakdowns because the ignition coil is mounted and operates in the engine compartment of a motor vehicle and is consequently subject to particularly critical mechanical stresses (vibrations) and thermal stresses (high temperatures). The limits to the extension of the permanent magnet are substantially dimensional limits because they would require that also the magnetic circuit have a cross section equal to the cross section of the permanent magnet.

[0007] Consequently, the permanent magnet has dimensional limits set by the relatively hostile environment in which the ignition coil operates, and consequently the

wide variations in magnetic induction required by the market cannot be reached. In practice, the limit of saturation of the magnetic circuit is often reached with a consequent sudden increase in the charge currents and in the thermal stress of the component. Consequently, the ignition coil reaches high temperatures that increase the risk of breakdown thereof.

[0008] An object of the present invention is to provide an ignition coil that will be free from the drawbacks just highlighted of the prior art. In particular, an object of the invention is to provide a reliable ignition coil capable of high performance and at the same time easy to produce and at a low cost.

[0009] In accordance with the above objects, the present invention relates to an ignition coil for triggering combustion in a controlled ignition endothermic engine, the ignition coil comprising: a magnetic circuit including a core, a cladding and a first permanent magnet; a primary electrical circuit wound around the core; and a secondary electrical circuit wound around the core and concatenated with the primary electrical circuit; the ignition coil being characterized in that it comprises at least one second permanent magnet, the first and second permanent magnets being set in parallel along the magnetic circuit.

[0010] Further characteristics and advantages of the present invention will emerge clearly from the ensuing description of two non-limiting examples of embodiment, with reference to the figures of the annexed plate of drawings, wherein:

- Figure 1 is a schematic view, with parts removed for clarity, of the ignition coil according to the present invention;
- Figure 2 is a schematic view, with parts removed for clarity, of a second embodiment of the ignition coil according to the present invention; and
- Figure 3 is a graph of the characteristic curve that links the magnetic induction with the magnetizing force of different ignition coils.

[0011] In Figure 1, designated by the reference number 1 is an ignition coil for triggering combustion in a controlled ignition endothermic engine and habitually housed in the engine compartment of a motor vehicle.

[0012] The ignition coil 1 comprises a magnetic circuit 2, a primary electrical circuit 3, and a secondary electrical circuit 4.

[0013] The magnetic circuit 2 comprises a core 5, which extends principally along an axis A, and a cladding 6, which extends along an annular path about the core 5 in the same plane as the axis A.

[0014] The primary electrical circuit 3 is wound around the core 5, and the secondary electrical circuit 4 is wound around the core 5 and is concatenated to the primary electrical circuit 3. In Figure 1, the arrows indicate the direction of the flux of the magnetic field along the magnetic circuit 2. The flux lines of the magnetic field arise

in an area corresponding to the core 5 of the magnetic circuit 2 and branch off on opposite sides along the cladding 6 of the magnetic circuit 2, and then join up again along the core 5 so as to form a characteristic path comprising two closed rings with a branch in common.

[0015] The magnetic circuit 2 further comprises a first permanent magnet 7 and at least one second permanent magnet 8 set in parallel. The first permanent magnet 7 and the second permanent magnet 8 are set in parallel along the cladding 6.

[0016] The magnetic circuit 2 is moreover divided into at least one first part 9 and one second part 10.

[0017] The first part 9 is substantially T-shaped and comprises the core 5 and a head 11, which is fixed to the core 5 and defines a portion of the cladding 6, whilst the second part 10 defines the remaining part of the cladding 6 and has two ends 12 and 13 close to the first part 9 of the magnetic circuit 2.

[0018] The first permanent magnet 7 and the second permanent magnet 8 are arranged between the first part 9 and the second part 10, respectively, in a position corresponding to the ends 12 and 13 of the second part 10.

[0019] The core 5 has a face 14, which is set in a direction orthogonal to the axis A in a distal position with respect to the head 11 and at a distance close to a respective face 15 of the second part 10 of the magnetic circuit 2, parallel to the face 14. The empty gap comprised between the face 14 of the core 5, in which the flux lines of the magnetic field enter, and the face 15 of the second part 10 of the magnetic circuit 2, from which the flux lines of the magnetic field exit, defines an air gap 16.

[0020] Figure 2 shows a second embodiment of the ignition coil 20 according to the present invention. Also in this figure, the arrows illustrated indicate the direction of the flux of the magnetic field. In this second embodiment, the ignition coil 20 comprises a magnetic circuit 21, a primary electrical circuit 22, and a secondary electrical circuit 23. The magnetic circuit 21 comprises a core 24, which extends principally along an axis B, and a cladding 25, which extends along an annular path about the core 24 in the same plane as the axis B of the core 24.

[0021] The magnetic circuit 21 further comprises a first permanent magnet 26 and a second permanent magnet 27 set in parallel, which are set in parallel along the cladding 25.

[0022] The magnetic circuit 21 is divided into a first part 28 and a second part 29. The first part 28 extends substantially along the axis B of the core 24 and comprises the core 24 and a head 30, which is fixed to the core 24 and defines a portion of the cladding 25, whilst the second part 29 defines the remaining part of the cladding 25 and has two ends 31 and 32 close to the first part 28 of the magnetic circuit 21.

[0023] The first permanent magnet 26 and the second permanent magnet 27 are arranged between the first part 28 and the second part 29 in a position corresponding to the ends 31 and 32 of the second part 29 of the magnetic circuit 21.

[0024] The core 24 has a face 33, which is set in a direction orthogonal to the axis B in a distal position with respect to the head 30 and at a distance close to a respective face 34 of the second part 29 of the magnetic circuit 21, parallel to the face 33.

[0025] The empty gap comprised between the face 33 of the core 24, in which the flux lines of the magnetic field enter, and the face 34 of the second part 29 of the magnetic circuit 21, from which the flux lines of the magnetic field exit, defines an air gap 35.

[0026] The first part 28 is able to slide with respect to the second part 29 in a direction substantially parallel to the axis B to enable adjustment of the dimensions of the air gap 35. In particular, the head 30 is in contact with the first permanent magnet 26 and the second permanent magnet 27 along surfaces of sliding 36 parallel to one another and parallel to the axis A. Sliding of the first part 28 with respect to the second part 29 along the surfaces of sliding 36 enables adjustment of the distance between the faces 33 and 34 of the air gap 35 during assembly of the ignition coil 20.

[0027] Figure 3 shows the qualitative evolution of a characteristic curve 37, which represents the magnetic induction B as a function of the magnetizing force H of the magnetic circuit 2 of the ignition coil 1 in which the plates of the magnetic circuit 2 are made of ferromagnetic material.

[0028] Designated by the reference number 38 is the point of rest, i.e. at zero current, on the hypothesis of a magnetic circuit 2 without permanent magnets. In this configuration (not shown in the attached figures), the maximum variation of magnetic induction B allowed with respect to the point of rest is indicated in Figure 3 by Δ_1 .

[0029] Designated by the reference number 39 is the point of rest, i.e. at zero current, in an ignition coil with a magnetic circuit having just one permanent magnet set along the core. In this ignition coil (not shown in the annexed figures), the maximum variation of magnetic induction B allowed with respect to the point of rest is indicated in Figure 3 by Δ_2 and is greater than the variation of magnetic induction Δ_1 allowed without the presence of the permanent magnet.

[0030] Designated by the reference number 40 is the point of rest, i.e. at zero current, on the hypothesis of a magnetic circuit 2 with two permanent magnets 7 and 8, made, for example, of Sm-Co (samarium-cobalt) or Nd-Fe-B (neodymium-iron-boron) and set in parallel according to the embodiment of Figure 1. In this configuration, the maximum variation of magnetic induction B allowed with respect to the point of rest is indicated in Figure 3 by Δ_3 and is even greater than the variation of magnetic induction Δ_2 allowed with the presence of just one permanent magnet set along the core 5.

[0031] Figure 3 moreover shows the qualitative evolution of a second characteristic curve 41, which represents the magnetic induction B as a function of the magnetizing force H of the magnetic circuit 2, the plates of which are preferably made of a ferromagnetic material with ex-

tremely high performance, such as for example iron and cobalt alloys.

[0032] The curve 41 is characterized by a slope, in the linear stretch, steeper than that of the curve 37 and above all is characterized by a linear stretch that is more extensive than that of the curve 37. The use of high-performance materials for the provision of the plates, in fact, entails raising of the saturation threshold in the characteristic curve B-H.

[0033] On the hypothesis of a magnetic circuit 2 made of a material that presents the pattern of the curve 41, with two permanent magnets 7 and 8 set in parallel according to the embodiment of Figure 1, it is possible to obtain a variation of magnetic induction Δ_4 greater than the variation Δ_3 of the curve 37 thanks to the increase in the saturation threshold.

[0034] Designated by the reference number 43 is the point of rest on the hypothesis of a magnetic circuit 2 with two permanent magnets 7 and 8 with high power of magnetization set in parallel according to the embodiment of Figure 1. In such a configuration, the variation of magnetic induction allowed is indicated by Δ_5 and is decidedly higher than the variations Δ_3 and Δ_4 .

[0035] The present invention presents the advantages described in what follows.

[0036] In the first place, the use of at least two permanent magnets, 7 and 8 or 26 and 27, set in parallel enables the dimensional limits imposed by the use of just one permanent magnet to be overcome. By setting two permanent magnets in parallel, in fact, an increase in the power of magnetization is obtained because the magnetic flux of the two branches in parallel of the magnetic circuit sum up, whilst the total reluctance of the magnetic circuit decreases because two reluctances in parallel are equivalent to one reluctance equal to one half. Consequently, the ignition coil 1 according to the present invention allows larger variations of magnetic induction B and hence enables high levels of reliability and of performance to be achieved.

[0037] In addition, the use of high-performance ferromagnetic materials, such as, for example, the iron and silicon alloys or even more iron and cobalt alloys, for making the plates that form the magnetic circuit 2 enables even larger variations of magnetic induction, further improving the performance of the ignition coil 1.

Claims

1. An ignition coil (1; 20) for triggering combustion in a controlled ignition endothermic engine; the ignition coil (1; 20) comprising: a magnetic circuit (2; 21), comprising a core (5; 24), a cladding (6; 25), and a first permanent magnet (7; 26); a primary electrical circuit (3; 22) wound around the core (5; 24); and a secondary electrical circuit (4; 23) wound around the core (5; 24) and concatenated with the primary electrical circuit (3; 22); the ignition coil (1; 20) being

characterized in that it comprises at least one second permanent magnet (8; 27); the first permanent magnet (7; 26) and the second permanent magnet (8; 27) being set in parallel along the magnetic circuit (2; 21).

2. The ignition coil according to Claim 1, **characterized in that** the first and second permanent magnets (7, 8; 26, 27) are set in parallel along the cladding (6; 25).
3. The ignition coil according to Claim 2, **characterized in that** the core (5; 24) extends principally along an axis (A; B) and the cladding (6; 25) extends along an annular closed path about the core (5; 24) and lies substantially in the same plane as the axis (A; B) of the core (5; 24).
4. The ignition coil according to any one of the preceding claims, **characterized in that** the magnetic circuit (2; 21) is divided at least into a first part (9; 28) and a second part (10; 29); the first part (9; 28) comprising the core (5; 24) and a portion of the cladding (6; 25), and the second part (10; 29) defining the remaining portion of the cladding (6; 25).
5. The ignition coil according to Claim 4, **characterized in that** the first and second permanent magnets (7, 8; 26, 27) are set in parallel between the first part (9; 28) and the second part (10; 29) of the magnetic circuit (2; 21).
6. The ignition coil according to Claim 5, **characterized in that** the second part (10; 29) comprises two ends (12, 13; 31, 32); the first and second permanent magnets (7, 8; 26, 27) being set, respectively, in a position corresponding to said ends (12, 13; 31, 32) in contact with the first part (9; 28).
7. The ignition coil according to any one of Claims 4 to 6, **characterized in that** it comprises at least one empty gap delimited by two parallel faces (33, 34) of the magnetic circuit (21), which defines an air gap (35); the first and second parts (28, 29) being able to slide with respect to one another for adjusting the distance between the faces (33, 34) of the said air gap (35).
8. The ignition coil according to Claim 7, **characterized in that** the first part (28) of the magnetic circuit (21) is able to slide with respect to the second part (29) of the magnetic circuit (21) in a direction parallel to the axis (B) of the core (24); the faces (33, 34) of the air gap (35) being orthogonal to the axis (B) of the core (24).

Fig.1

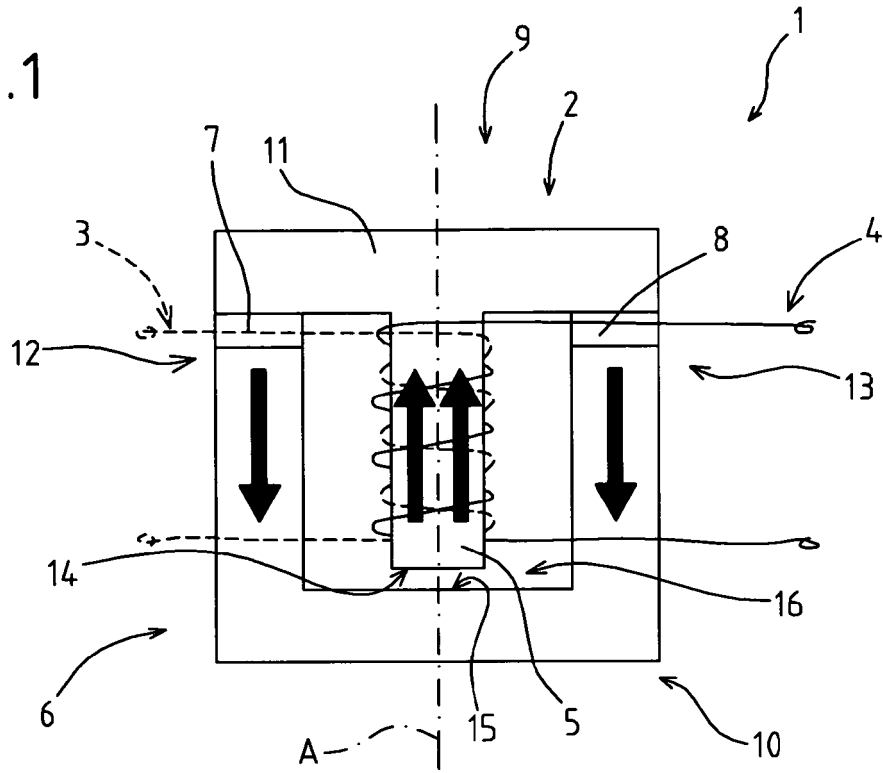
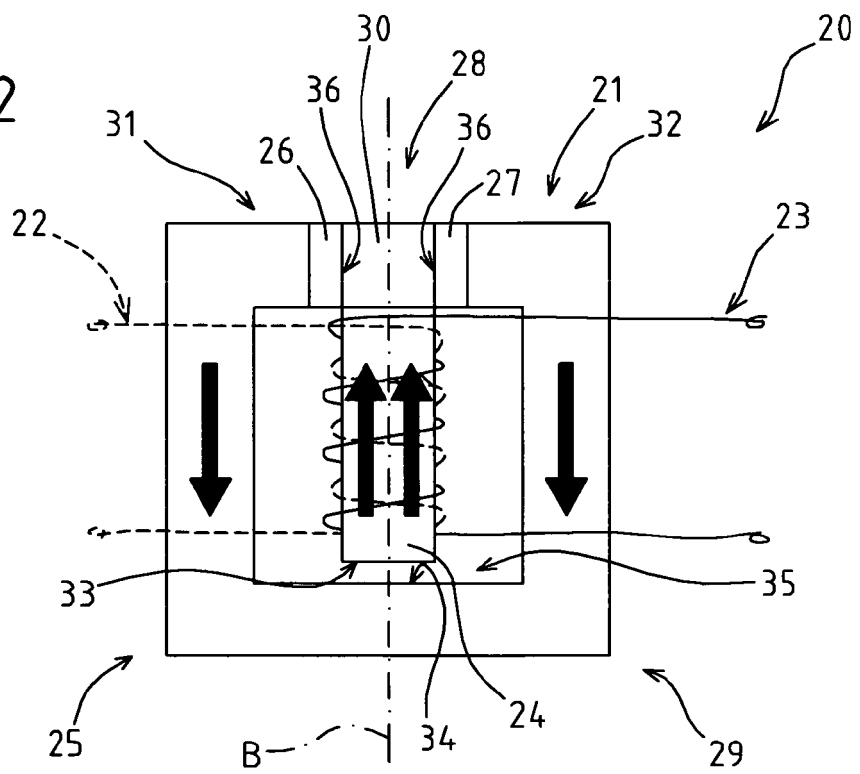


Fig.2



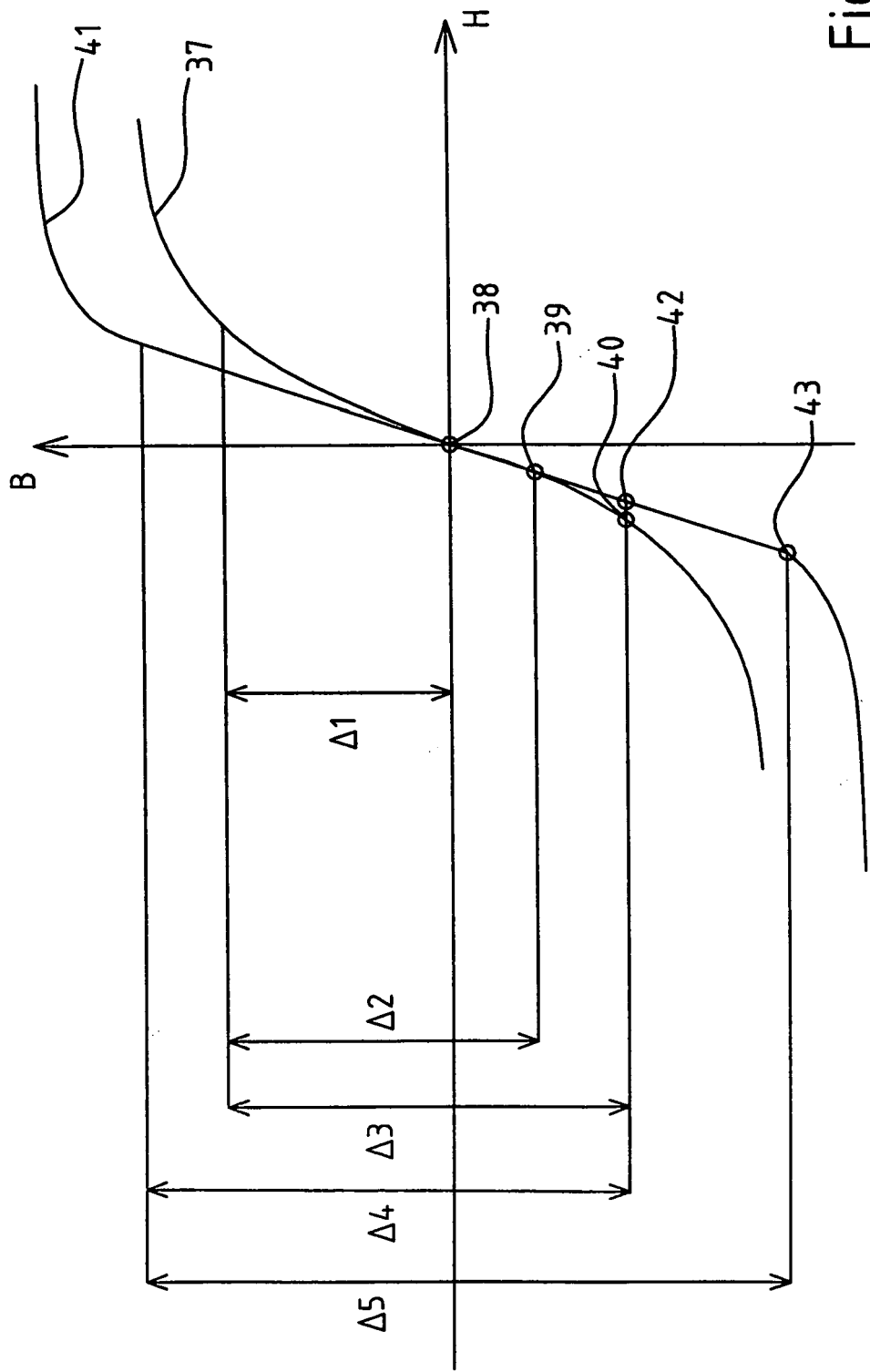


Fig.3



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 42 5582

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2002/171524 A1 (TSAI MU-SHUI [TW]) 21 November 2002 (2002-11-21) * paragraph [0020] - paragraph [0023]; figures 1-3 * * paragraph [0026] *	1-8	INV. H01F38/12 H01F3/10
X	DE 22 26 289 A1 (TDK ELECTRONICS CO LTD) 4 January 1973 (1973-01-04) * page 31 - page 32; figures 35,36A *	1-8	
X	US 6 211 763 B1 (MORITA SHINGO [JP]) 3 April 2001 (2001-04-03) * column 6, line 65 - column 10, line 30; figures 1-4 *	1-8	
A	US 3 209 294 A (CORNELL ARCHIE R) 28 September 1965 (1965-09-28) * column 1, line 10 - line 55 * * column 2, line 14 - line 52; figure 1 * * column 3, line 2 - line 30; figures 3,4 * * column 3, line 67 - line 72; figure 6 * * column 4, line 29 - line 42; figures 7,8 * * column 4, line 65 - line 74 *	7,8	TECHNICAL FIELDS SEARCHED (IPC) H01F
A	US 4 480 377 A (HOUSE RONNALEE [US] ET AL) 6 November 1984 (1984-11-06) * column 1, line 5 - line 62 * * column 2, line 46 - column 4, line 67; figures 1-3 *	7,8	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 12 January 2007	Examiner Teske, Ekkehard
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03.02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 06 42 5582

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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12-01-2007

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002171524 A1	21-11-2002	NONE	
DE 2226289 A1	04-01-1973	NONE	
US 6211763 B1	03-04-2001	NONE	
US 3209294 A	28-09-1965	NONE	
US 4480377 A	06-11-1984	CA 1192636 A1	27-08-1985
		DE 3370402 D1	23-04-1987
		EP 0104792 A1	04-04-1984
		JP 1044003 B	25-09-1989
		JP 59078516 A	07-05-1984