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(54) **Multipole magnetizing device and method for producing such device**

(57) A multipole magnetizing device uses a solid multipolar magnetizing head to carry out magnetization of permanent magnets, made of highly coercive materials such as hard magnetic ferrites and rare earths based materials, that require a very high magnetic field strength concentrated on precisely defined sections to reach the point of magnetic saturation.

The magnetization is carried out within a multipolar magnetizing head in such a way, that a series of symmetric and alternately opposite poles are produced on the permanent magnet. The magnetizing head has a shape of a tubular body, made of a material having good electrical conductivity. A succession of opposite current loops is created in the magnetizing head by appropriate geometry of vertical cuttings in the tubular body of the magnetizing head. The shape of the current loops ensures that the main portion of the electric current is sufficiently close to the surface of the magnet material. The width of the magnetic poles is defined by the gaps between the said cuttings.

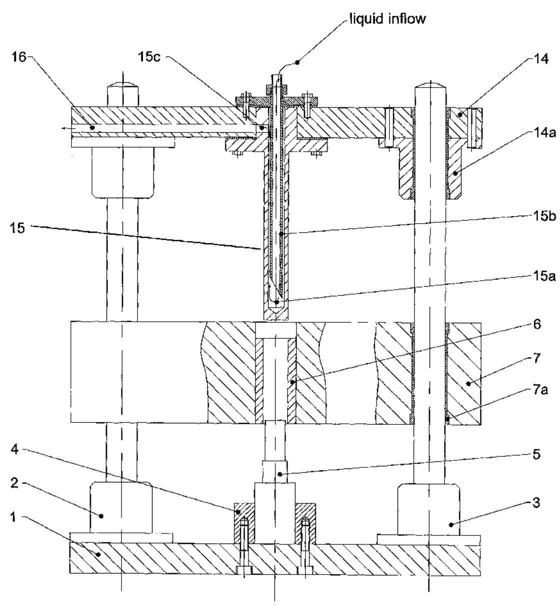

Fig. 1

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Description

FIELD OF INVENTION

[0001] This invention relates in general to apparatus and processes for magnetizing and demagnetizing hard magnetic materials, and in particular to multipole magnetizing devices.

BACKGROUND

[0002] The present invention concerns a device for multipolar magnetization of hard magnetic materials, such as rare earths and ferrites, and a method for producing such magnetizing device. To reach the point of magnetic saturation, the hard magnetic materials require a very high magnetic field strength concentrated on precisely defined sections. The device should withstand high mechanical loadings produced by magnetic forces of the strong magnetic field. Besides, the magnetizing device warms itself intensively as the magnetic field is generated by high current impulses. So, the design of the magnetizing device and the method for producing the said device should be such as to ensure that the geometrical form of the device would be precise and symmetric and that the heat released during the magnetization process would be conveyed away efficiently. In the patent US4470031 a multipolar magnetizing device for permanent magnets is described, having a supporting structure, which can be either a solid block, or a series of superimposed sheets, made of electrically insulating material, which may be of fiberglass, with prepared apertures to receive the electrically conductive magnetizing winding. The apertures are arranged to firmly support the winding to prevent displacement despite the strong magnetic fields generated by a high-current impulse discharge. The winding can be arranged to produce a variety of polar patterns on flat magnets or, by providing a suitable opening in the supporting structure, on cylindrical magnets.
Highly coercive magnet materials are known to be magnetized primarily with high current pulses through a current conductor arranged to form a sequence of current loops around a round magnet, or a sequence of current loops along the flat magnet. In the material to be magnetized the required magnetic field is created by means of the said current loops, which are generally made of wire in prior art magnetizers.

SUMMARY OF THE INVENTION

[0003] The essential aspect of the magnetizing device according to the present invention is that it can magnetize highly coercive magnet materials, such as rare earths, which require a high value of magnetic field strength to reach the point of magnetic saturation. The device is designed to concentrate the magnetic field on very thin sections enabling narrow magnetic pole pitches to be formed; consequently, a series of pole pairs can be arranged around a cylindrical magnet or along the surface of a flat magnet. Another object of the invention is to provide a stable magnetizing process as well as small dissipation of widths and amplitudes of the magnetic fields of the pole pairs. This object is achieved by ensuring suitable accuracy of the geometric shape of the magnetizing head.

DETAILED DESCRIPTION OF THE INVENTION

[0004] The multipole magnetizing device according to the present invention and the method for producing such device will be better understood by means of the drawings wherein

FIG. 1	is a front plan view of the device in accordance with the invention, including the section views of some portions of the device;
FIG. 2	is a front plan view of the body 8;
FIG. 3	is a side plan view of the body 8 of the multipolar magnetizing head 6;
FIG. 4	is a top plan view of the body 8 of the multipolar magnetizing head 6;
FIG. 5	is a transverse section of the body 8;
FIG. 6	shows a diagram of the magnetic potential and magnetic density in the magnetizing slot;
FIG. 7	is an illustration of the main portion of the current flow during the pulse magnetizing.

[0005] The frame structure of the multipole magnetizing device consists of a base 1, two supports, 2 and 3, affixed on the edges of the base 1, and a cooling plate 14, which is affixed to the supports 2 and 3 by means of fastening sockets 14a. In the center of the base 1 a support 4 for a thorn 5 is affixed, the thorn 5 being designed to accept the magnet, which should be magnetized. A magnetizing head 6 is disposed in the center of a mechanical protecting block 7 in such a way, that its longitudinal axis coincides with the longitudinal axis of the thorn 5. The block 7 with the integrated magnetizing head 6 is fastened onto the supports 2 and 3 in such a manner that it can be moved along the said supports. The block 7 is made of nonconductive and non magnetizable material and has adequate mechanical strength to ensure proper support to the magnetizing head 6 in its radial direction, so that the magnetizing head can withstand high forces of strong magnetic field produced by high-current impulses.
In the center of the cooling plate 14, which comprises a longitudinal conduit 16 for outflow of cooling liquid, a cooling thorn 15 is affixed, which has a cooling system built in such a way, that within the thorn 15 a tube 15b is inserted, which is to a small degree thinner than the cylindrical cavity of the thorn (15) and is cut obliquely on its lower end. The cooling liquid flows downwards the tube 15b to the end of the cooling thorn 15, where the liquid is turned upwards to flow between the outer wall

of the tube 15b and the wall of the cylindrical cavity of the thorn 15 towards the outlet conduit 16 in the cooling plate 14.

The multipole magnetizing head 6 is manufactured in the shape of a tubular body 8, made of a solid material, which must be a good electrical conductor. In the body 8, vertical cuttings 9 and 11 are arranged in alternating succession, the said cuttings being cut across the entire width of the wall of the body 8, while in vertical direction their length is equal to approximately 8/9 of the height of the body 8, wherein the said cuttings 9 commence at the top of the body 8 and the said cuttings 11 commence at the bottom of the body 8. Between the first and the last cutting 9, to which the terminals 12 and 13 are connected, instead of a cutting 11 a cutting 10 is made, which runs across the entire height of the body 8.

The sequence of cuttings 9, 10 and 11 forms a series of electrically conductive columns in the body 8. The geometric shape of the columns creates a current loop that begins at cutting 10. Through the terminals 12 and 13 the current flows along the current loops in the columns of the magnetizing head 6 in such a way that the direction of current in adjacent columns is opposite. The shape of the columns that form the current loop ensures that during magnetizing process the main portion of the current is sufficiently close to the surface of the magnet material, which is evident from the figure 6. The width of the magnetic poles is defined by the arrangement of cuttings 9, 10, and 11 around the body 8, i.e. by the gaps between the said cuttings. The best conditions can be achieved by lamellization of the body 8, as in this case at high current impulses with the order of magnitude of 80 kA the order of magnitude of the magnetic flux density on the surface of the magnetic material can be 2 T. The cuttings 9, 10, and 11 on the body 8 of the magnetizing head 6 can be produced by means of wire erosion or immersing erosion process or by any other metal removal process. These processes can produce geometrically precise symmetric current conducting paths ensuring thereby the required symmetry of magnetic poles. In addition, focusing of the magnetic field in narrow portions of the magnetic material can be achieved. The symmetry of the magnetic poles is important also as it ensures compensation of strong transversal forces arising due to high current impulses in the magnetizing head 8. An efficient compensation of transversal forces prolongs the life span of the magnetizing device. Adequate mechanical strength of the magnetizing device is accomplished by the precise geometrical shape of the body 8 and the cuttings 9, 10, and 11, which provide the required symmetry of current conducting paths and thereby ensure a uniform distribution of forces against the supporting walls of the mechanical protecting block 7.

[0006] The openings of the cuttings 9, 10, and 11 separating the individual current paths are filled with synthetic resin re-enforced with glass fibers or Kevlar® fibers.

As the current conductive section of the device in which high energy is released during magnetization process, is surrounded by a material that can withstand strong mechanical forces yet is a bad heat conductor, the removal of heat is carried out by means of the cooling thorn 15, which is made of material with good heat conducting properties and is also cooled by means of a cooling system integrated in the thorn, the said cooling system ensuring efficient removal of heat from the thorn 15. Besides, by means of cooling liquid the cooling thorn 15 releases the heat also into the cooling plate 14. When the magnetization process is finished, the mechanical protecting block 7 with the integrated magnetizing head 6 is moved towards the cooling thorn 15, which is thereby inserted into the vacant place where the permanent magnet was installed during the magnetization process. As a consequence, the thorn 15 is brought into physical contact with the columns of the body 8, i.e. with the current conducting paths, and can therefore accept the built-up heat energy even faster. The cooling time is defined so that a working temperature around 100°C is maintained to ensure longer life span of the device and a stable magnetization process.

In the alternative embodiment I of the present invention the body 8 is made of an insulated band, which is a good electrical conductor. In a device for magnetizing flat magnets, the said insulated band is formed in the shape of a block, while in a device for magnetizing cylindrical magnets the said band is rolled into a coil of a toroidal shape.

In the alternative embodiment II of the present invention the body 8 is made of insulated concentric tubes, which are put together into a block in the case of a device for magnetizing flat magnets, while in the case of a device for magnetizing cylindrical magnets, the said insulated concentric tubes are rolled into a coil having a toroidal shape. As a consequence, the current conducting paths have a rectangular section, when the body 8 is formed into a block, and a section in the form of a ring, when the body 8 has a cylindrical shape.

The number of possible pole pairs in the body 8 can be expressed by means of the following equation: $p = 1 + N$, where N represents the multitude of natural numbers. By means of the multipole magnetizing device in accordance with present invention high intensity magnetic field can be produced: the order of magnitude of the magnetic field intensity can be as high as 2500 kA/m. Besides, such intensity can be generated on very narrow sections around a cylindrical magnet or along the surface in case of a flat magnet. Such high intensity is necessary for magnetizing rare earth magnetic materials as demonstrated in the figures 6 and 7.

Claims

1. A multipole magnetizing device for producing multipolar permanent magnets with symmetric and

alternately opposite poles, whereby the permanent magnets are made of highly coercive materials such as hard magnetic ferrites and rare earths based materials, **characterized in that** the frame structure of the device consists of a base (1), two supports (2 and 3) affixed on the edges of the base (1), and a cooling plate (14) affixed to the supports (2 and 3) by means of fastening sockets (14a); that In the center of the base (1) a support (4) for a thorn (5) is affixed, the thorn (5) being designed to accept the magnet, which should be magnetized; that a magnetizing head (6) is disposed in the center of a mechanical protecting block (7) in such a way, that its longitudinal axis coincides with the longitudinal axis of the thorn (5); that the block (7) with the integrated magnetizing head (6) is fastened onto the supports (2 and 3) in such a manner that it can be moved along the said supports; that the block (7) is made of nonconductive and non magnetizable material and has adequate mechanical strength to ensure proper support to the magnetizing head (6) in its radial direction; that in the center of the cooling plate (14), which comprises a longitudinal conduit (16) for outflow of cooling liquid, a cooling thorn (15) is affixed, which has a cooling system built in such a way, that within the thorn (15) a tube (15b) is inserted, which is to a small degree thinner than the cylindrical cavity of the thorn (15) and is cut obliquely on its lower end.

2. A device as in claim 1, wherein the multipole magnetizing head (6) is manufactured in the shape of a tubular body (8), made of a solid material, which must be a good electrical conductor; that in the body (8) vertical cuttings (9) and (11) are arranged in alternating succession, the said cuttings being cut across the entire width of the wall of the body (8), while in vertical direction their length is equal to approximately 8/9 of the height of the body (8), wherein the said cuttings (9) commence at the top of the body (8) and the said cuttings (11) commence at the bottom of the body (8); that between the first and the last cutting (9), to which the terminals (12 and 13) are connected, instead of a cutting (11) a cutting 10 is made, which runs across the entire height of the body (8).

3. A device as in claims 1 and 2, wherein the tubular body (8) of the multipole magnetizing head (6) is made of an insulated band, which is a good electrical conductor and which is rolled into a coil of a toroidal shape.

4. A device as in claims 1 and 2, wherein the tubular body (8) of the multipole magnetizing head (6) is made of an insulated band, which is a good electrical conductor and which is formed in the shape of a block.

5. A device as in claims 1 and 2, wherein the tubular body (8) of the multipole magnetizing head (6) is made of insulated concentric tubes.

6. A device as in claims 1 to 5, wherein the cuttings in the tubular body (8) of the multipole magnetizing head (6) are produced by means of a wire erosion or immersing erosion process and wherein the openings of the cuttings are filled with synthetic resin re-enforced with glass fibers or Kevlar® fibers.

7. A device as in claims 1 to 5, wherein the cuttings in the tubular body (8) of the multipole magnetizing head (6) are produced by means of a metal removal process and wherein the openings of the cuttings are filled with synthetic resin re-enforced with glass fibers or Kevlar® fibers.

8. A device as in claims 1, wherein during the magnetizing process and especially upon the conclusion of the magnetizing process the cooling liquid is conveyed through the cooling system of the device, first downwards through the tube (15b) disposed in the cooling thorn (15), then upwards between the outer wall of the tube (15b) and the wall of the cylindrical cavity of the thorn (15) towards the outlet conduit (16) disposed in the cooling plate (14), and finally through the outlet conduit (16).

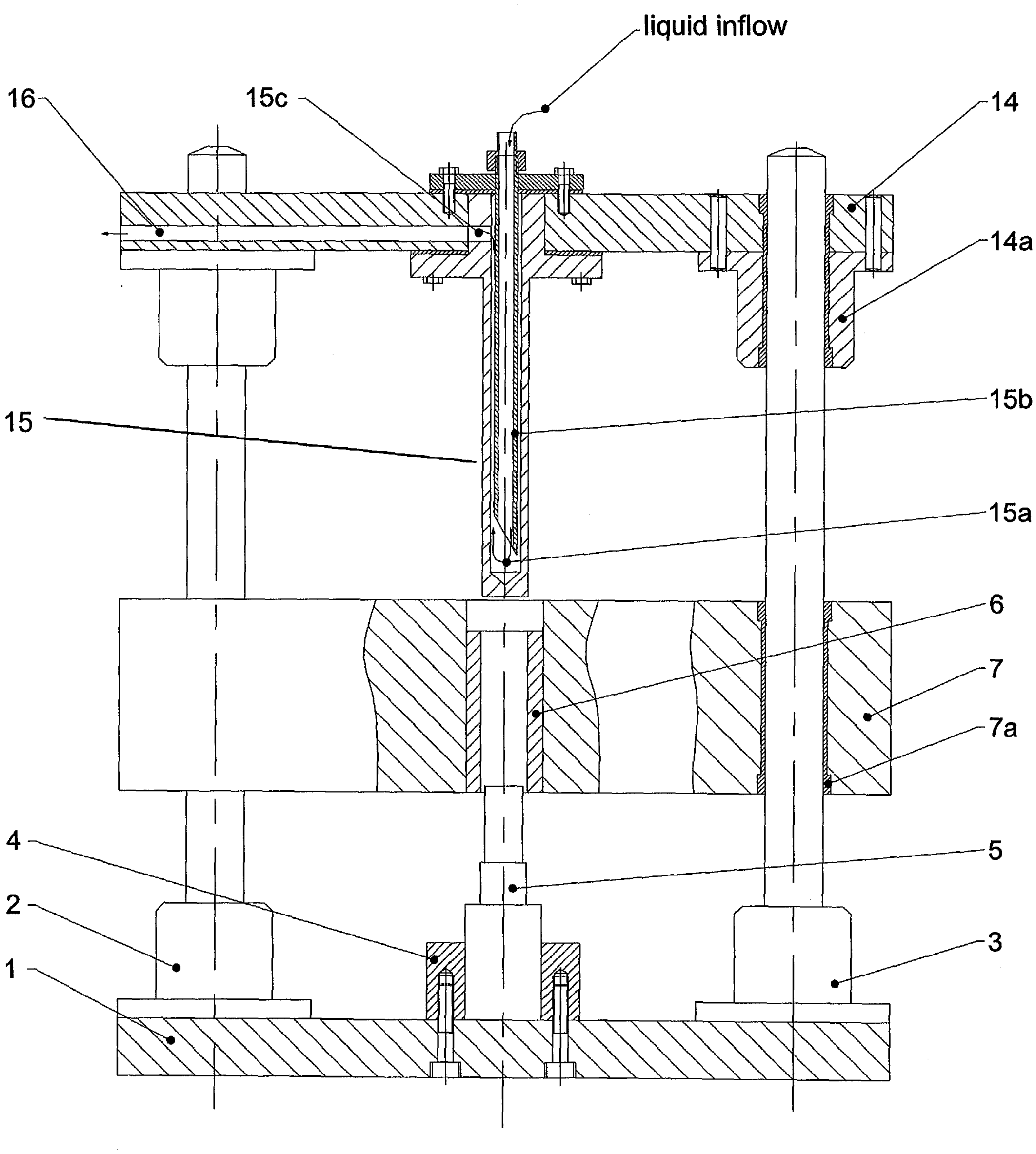


Fig. 1

A - A

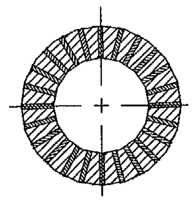


Fig. 5

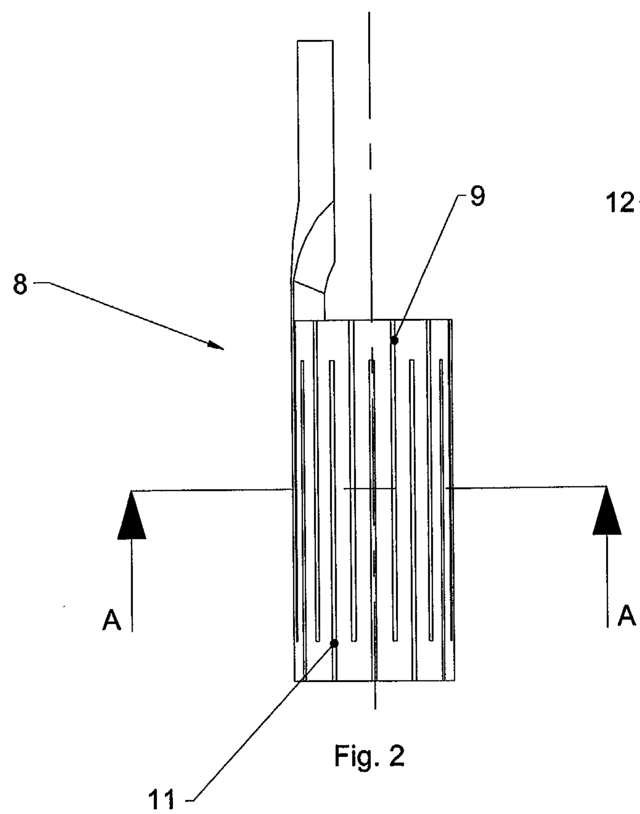


Fig. 2

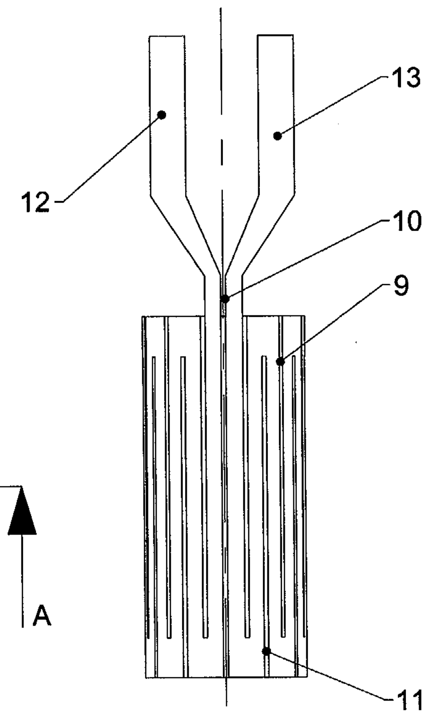


Fig. 3

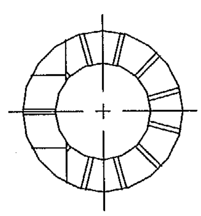
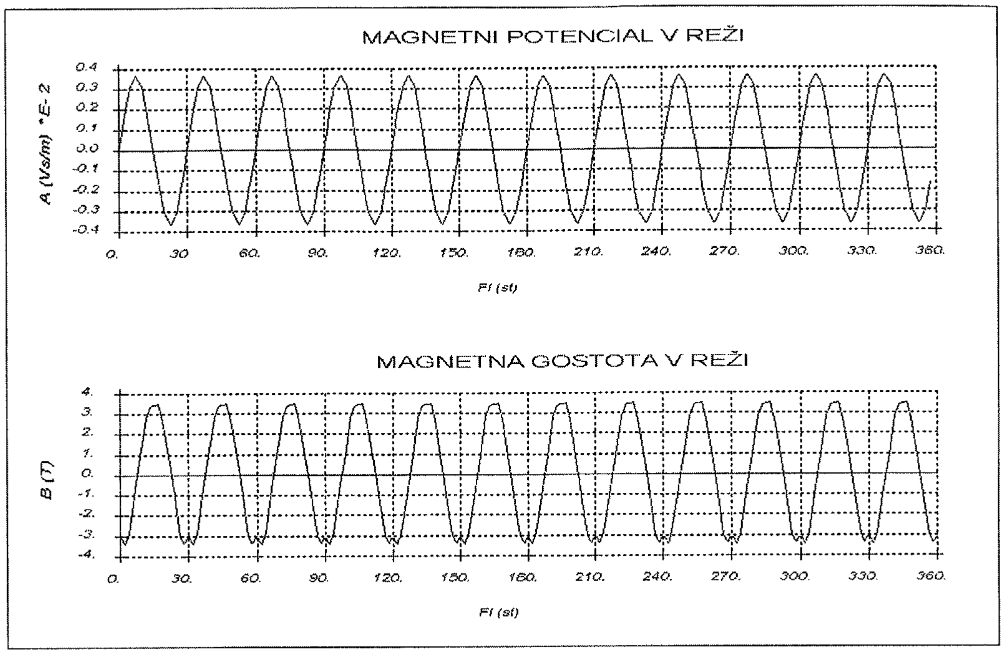


Fig. 5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MAGNETNA GOSTOTA V REŽI
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Fig. 6

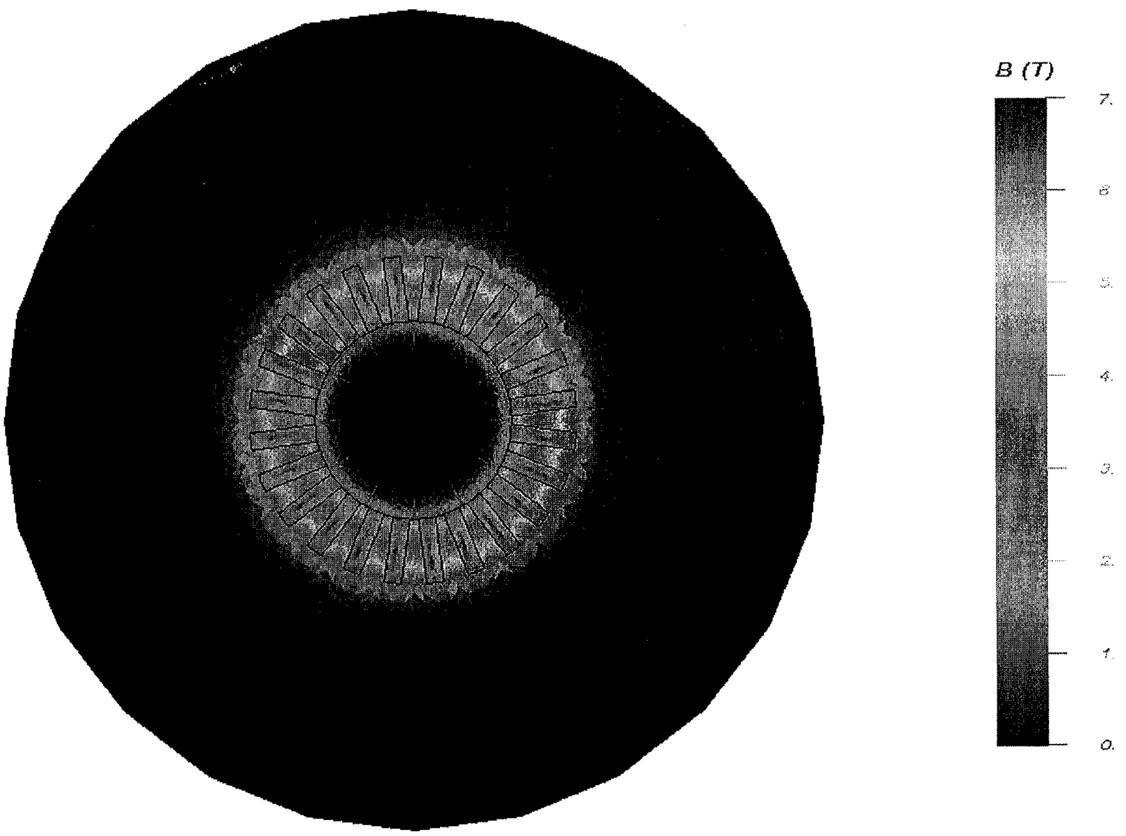
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Fig. 7