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[Continued on next page]

(54) Title: METHOD FOR MANUFACTURE OF TRANSFORMER CORES, A METHOD FOR MANUFACTURE OF A TRANSFORMER HAVING SUCH CORE AND A TRANSFORMER MANUFACTURED ACCORDING TO THIS METHOD

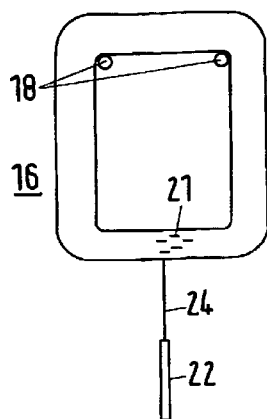


Fig. 2a

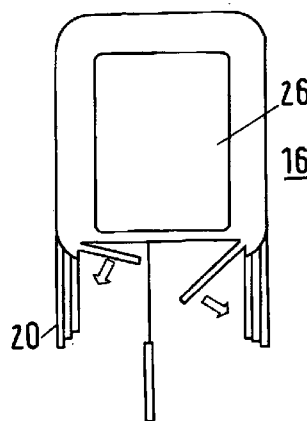


Fig. 2b

(57) Abstract: The invention relates to a method for manufacture of a transformer core made of ferromagnetic material, such as amorphous metal or silicon iron, which is provided as a single ribbon layer or as multiple ribbon layers, characterized by the following steps : a) the single ribbon layers or bundle of ribbon layers of ferromagnetic material, such as amorphous metal or silicon iron, are continuously wound into loops, whereas the shape of the core loops is effected by means of an appropriate mandrel to be directly formed into its final shape; b) the single or multiple ribbon layers of the loops are being cut in that - a mechanical device or a laser is used for cutting, allowing fast and precise cutting of the ribbons, and in that - all ribbons of the loops are cut at at least one position along the circumference of each ribbon layer. Furthermore the invention relates to a method of manufacture of a transformer having a core manufactured according to the method being illustrated before as well as to a transformer provided with such a core manufactured according to the claimed method.



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Method for Manufacture of Transformer Cores, a Method for Manufacture of a Transformer having such Core and a Transformer Manufactured according to this Method

Description

The invention relates to a method for manufacture of a transformer core made of ferromagnetic material, such as amorphous metal or silicon iron, which is provided as a single ribbon layer or as multiple ribbon layers wound on a winding mandrel.

A major component of a transformer is its core with the purpose of guiding the magnetic flux whereas the core usually consists of laminated steel laminations. Transformers for use at power typically have cores made of high permeability silicon steel which has a permeability many times that of free space, and the core thus serves to greatly reduce the magnetizing current, and confine the flux to a path which closely couples the windings.

Early transformer developers soon realized that cores constructed from solid iron resulted in prohibitive eddy-current losses, and their designs mitigated this effect with cores consisting of bundles of insulated iron wires. Later designs constructed the core by stacking layers of thin steel laminations, a principle that has remained in use. Each lamination is insulated from its neighbors by a thin non-conducting layer of insulation.

The effect of laminations is to confine eddy currents to highly elliptical paths that enclose little flux, and so reduce their magnitude. Thinner laminations reduce losses, but are more laborious and expensive to construct. Thin laminations are generally used on high frequency transformers

Accordingly the transformer core causes energy losses due to hysteresis and eddy currents. The use of amorphous metal (typically FeBSi alloy) instead of Si-steel as core material allows to significantly reducing these losses. Due to the higher energy efficiency of amorphous transformers they find increasing application. The manufacturing of the cores is labor intensive and costly. This ID presents an alternative manufacturing method which allows simplifying several of the manufacturing steps

From EP 0357357A1 a method of constructing a transformer having an amorphous steel core has become known having a coil about a leg of the core wherein the core leg is formed to a cross section that more closely conforms to the configuration of the coil window of the coil that surrounds the core leg. The core leg is formed of superposed strips of amorphous steel which are somewhat thicker in their central region than at their edges and which are squeezed together at their edges to form the con-formal cross-section.

According to US 4814736A a transformer core is made by winding a strip of ferromagnetic material, such as amorphous metal or silicon iron, on a winding mandrel to form a first annulus and cutting once through this annulus to create a plurality of individual laminations which are then assembled in packets about a nesting mandrel of a smaller diameter than the winding mandrel to form a second annulus. Each packet consists of a predetermined number of groups of laminations, with the ends of each lamination group lapping each other to form a lap joint.

The lap joints of each packet are arranged in staggered positions to create a repeating step-lap joint pattern confined within a predetermined joint region. By decreasing the lap joint dimension and increasing the number of groups in successively assembled packets, the increase in build of the joint region over that of the remainder of the second annulus is minimized.

Hence it is an object of the present invention to provide a new method for easier manufacturing of a transformer core, a method for manufacture of a transformer hav-

ing a core being manufactured according to the claimed method, and such transformer thus having improved effectiveness in operation.

Accordingly the invention provides an alternative manufacturing method which allows simplifying several of the manufacturing steps. In particular the claimed method is characterized by the following steps

- a) the single ribbon layers or bundle of ribbon layers of ferromagnetic material, such as amorphous metal or silicon iron, are continuously wound into loops, whereas the shape of the core loops is effected by means of an appropriate mandrel to be directly formed into its final shape;
- b) the single or multiple ribbon layers of the loops are being cut in that
 - a laser is used for cutting, allowing fast and precise cutting of the ribbons, and in that
 - all ribbons of the loops are cut at at least one position along the circumference of each ribbon layer.

While according to the teaching according to the state of the art known from US 481736A the strips of amorphous metal are provided for the single layers of the core each forming an annulus with the respective diameter being cut into the length according to its later position, with this invention the foil of amorphous metal is wound continuously until the final shape of the core is achieved. This is an essential feature of the invention.

Only then the cutting takes place by means of a mechanical cutting device or of laser cutting which allows precise and fast cutting as well as automated operation of the mounting equipment while the mechanical cutting of the tapes or ribbons respectively of the bundle of ribbons as a conventional method is possible, too, and is adopted in case when the laser equipment is not available or the layers of tape have a thickness which is not appropriate for laser cutting.

According to a further essential feature of the invention laser cutting instead of mechanical cutting has been provided as well as the continuous winding of the ribbons of ferromagnetic material, such as amorphous metal or silicon iron, forming the core until the final shape has been achieved.

Consequently laser devices are being provided for cutting the ribbon like foils with respect to the specifically required width corresponding to the desired design and the winding apparatus by which the ribbon with the specific width is wound continuously until the core has achieved its final shape.

In this regard the laser cutting device and the spooling mechanism may be manually operated, but preferably it is partly or fully automated which is advantageous for the handling with the spooling of the ribbon.

As already mentioned laser cutting is more reliable and more precise as to the trimming of the borders than the customary mechanical cutting, especially with regard to the surface quality of the respective cut line.

A further preferred provision is characterized in that the winding axis has a horizontal or vertical or any other direction.

For displacement of the positions of the cuts, either the core or the laser beam are being displaced, or the direction of the laser beam is being adjusted. Alternatively the laser beam is being displaced by one or several mirrors.

Furthermore according to a preferred embodiment of the claimed invention the single ribbon layers or bundles of layers can be wound at a time, i.e. simultaneously.

According to one preferred embodiment of the invention the winding process of the ribbon is being executed fully or partly by automatic equipment, though likewise manually operated equipment is applicable.

Advantageously the winding axis can be provided to have horizontal or vertical direction or any other direction. In case of Evans cores, which finally comprise three core legs, the outer loop can directly be wound on the two inner loops.

According to an improvement of the invention it is provided that during the winding process strips of different material can locally be inserted into the winding. These inserts can be introduced between each ribbon layer respectively between any bundle of layers. The purpose of these inserts is to limit the depth of the cuts.

A preferred embodiment of the claimed invention concerning the positioning of the laser is characterized in that the laser is positioned below the core respectively the loop for cutting. In this case the ribbon layers are enabled to open up (unlace) by gravitational force.

Preferably according to a further embodiment of the claimed method the inserts can be displaced, and thus allowing a stepped butt configuration. Consequently the inserts can be made of amorphous metal, Si-steel, other metal foils or polymeric foils, whereas a preferred polymeric foil is made from PTFE.

If inserts are being provided, according to a further improvement of the invention the cuts are effected at the position of the inserts within the core. If any inserts are present in the core, such inserts are removed after effecting the cuts.

Furthermore according to an advantageous embodiment of the invention it is provided that other than straight cuts are effected, e.g. a wave-shaped cut which helps to improve the magnetic flux and reduce losses and excitation current.

Such shapes are easily feasible with laser cutting. In case of an Evans core the cuts can be made on the complete core consisting of up to 3 loops whereas the two inner loops can be cut in parallel for reducing the total processing time.

In case that bundle of layers are cut, the individual layers advantageously weld together at the cut which simplifies the handling during re-lacing.

In order to support the shaping of the core body for the time when the mandrel has been removed from the core it is provided that temporarily the core is fixed by means of a mold or any other appropriate support, e.g. clamps or the like.

According to a further essential embodiment of the invention after removal of the mandrel the wound core body is annealed for at least ½ hour at about 350°C in order to equalize the structure of the amorphous metal.

Preferably the annealing takes place when the core body is complete i.e. that the loop is still closed and not yet unlaced, i.e. opened. But according to another embodiment of the invention it is provided that the cutting of the core body is effected before the annealing procedure has been initiated. Due to laser cutting which is an

essential feature of the invention it does not matter when the annealing procedure of the core takes place i.e. before or after cutting the loop.

Accordingly the core is being annealed when it is unlaced in order to give access to the core legs which are formed by the long sides of the core.

Then, in order to enforce the core mechanically preferably only the core legs including the lower part of the core which connects the core legs are coated with resin or a different polymeric material which provides as well mechanical stability as protection against mechanical wear.

However, preferably the coating of the core legs is effected after annealing the core, i.e. after it has been annealed, and before it is unlaced, i.e. opened, in order to make then the core legs accessible for receiving the respective transformer coils.

But no problem, it would also be possible to do the coating after unlacing of the core when it is already opened.

After re-lacing the core i.e. closing the core the rest of the core is coated, too. At this stage, i.e. when the coating has been cured the core is ready for use as a transformer core.

Furthermore, an object of the invention is to disclose a new method for manufacture of a transformer using such a core as described before. A method for manufacture of a transformer having a core made of amorphous metal as it has been illustrated before is characterized by the following steps

- a) after the winding of the ribbons consisting of ferromagnetic material, such as amorphous metal or silicon iron, has been finished the core is provided with supports in order to maintain the shape of the core and one side of the core loop is being cut by means of laser cutting whereas prior to or after the cutting of the core an annealing procedure takes place;
- b) after the annealing procedure the cut ends of the respective core loop are bent up so that the core legs are accessible;

- c) then at least the lower part of the core comprising the core legs and its connecting part is coated with resin or a different polymeric material in order to make it mechanically stable,
- d) on at least one core leg at least one transformer coil is shifted and
- e) then the opened core is re-laced and the not yet coated part of the core is coated.

With transformers having a core of amorphous metal the core and the coils are manufactured separately and then assembled. This requires that the core is opened for inserting the coils.

Most advantageously according to one further embodiment of the invention the core is provided for an annealing procedure which is executed after removing of the mandrel which is provided for manufacture of the core.

Hence it is essential for the integrity of the transformer core which consists of a plurality of thin layers of foil to prevent the core from breaking down and losing its shape. When the mandrel has been removed from the core instead of the mandrel other devices are being provided to maintain the shape of the core such as supports, molds or clamps.

These features as well as some advantageous improvements and advantages will be illustrated comprehensively and explained by means of some drawings being attached herewith in the following.

Brief description

In particular it is shown in

- Fig. 1 four stages of manufacture of a transformer with a core made from amorphous metal according to the state of the art in lateral view;
- Fig. 1a 1st stage: finished core;
- Fig. 1b 2nd stage: opening of the core for forming core legs;

Fig. 1c 3rd stage: insertion of coils on the core legs;

Fig. 1d 4th stage: closing the core;

Fig. 2a core loop manufactured according to the invention and being formed by a plurality of ribbons of amorphous metal being supported by core supports where a laser is provided for the cutting of the ribbons in lateral view;

Fig. 2b core loop manufactured according to the invention and being formed by a plurality of ribbons of amorphous metal being supported by core supports where some ribbons have been cut already by the laser in lateral view;

Fig. 3 a similar arrangement as shown in Fig. 2a but here with an Evans core in lateral view;

Fig. 4a a similar arrangement as shown in Fig. 2a but here with a core loop on a trapezoid mandrel in lateral view and

Fig. 4b a staggered step-lap rectangular core loop after relacing. in lateral view

Description

In Fig. 1a to 1d four stages of manufacture of a core 10 for a transformer according to the state of the art whereas the core 10 of is made from single stacked layers of amorphous metal. All these figures are shown in lateral view.

In particular Fig. 1a shows a 1st stage of the manufacturing process when the core has been finished. This process is executed by ccutting of the amorphous ribbon to the appropriate length. The cutting is done by a metal shears, which is a Guillotine-

like device. Typically a bundle or a number of layers is cut simultaneously. The outer layers of a core need to be longer than the inner layers. This requires permanent adjustments of the cutting length

Fig. 1b shows a 2nd stage when the core has been opened respectively when the ribbons have been unlaced for forming core legs where coils are received. This unlacing of the single layers is usually done manually by means of mechanical equipment.

In Fig. 1c a 3rd stage of the conventional method has been shown where the core legs 12 receive the provided coils.

Finally in Fig. 1d the 4th stage of the conventional method shows a closed core whereas the formerly unlaced ribbons are being re-laced and the core is being closed again.

In figures 2 to 4 the various steps and principles and methods according to the claimed invention are shown. All reproductions present the respective cores in lateral view.

Fig. 2a shows a rectangular core loop 16 manufactured according to the invention and being formed by a nearly endless i.e. continuously wound ribbon (not shown in detail) of amorphous metal being supported by core supports 18 which keep the core in shape.

According to one preferred embodiment of the invention the positioning of the core 16 has been provided in that way that the cut for unlacing the ribbons and thus for opening the core 16 is effected from below.

This specific kind of cutting the ribbons results in self-acting opening of the respective core by means of gravity which forces the ends of the ribbons to bend accordingly and release the access to the core legs 20 as shown partly in Fig. 2b.

As a tool for effecting of the cut of the ribbons according to the invention a laser 22 is being provided whereas the laser provided for the cut is directing its beam 24 to the ribbons from below of the core 16 accordingly. Additionally locally, e.g. between each layer of the ribbons, some inserts 21 are being introduced in order to limit the depths

of the cuts effected by the laser.

Different from the arrangement shown in Fig. 2a the core 16 according to Fig. 2b is being supported by a mandrel 26 which is to be removed when the cut of the ribbons has been finished in order to allow the core legs 20 of the core 16 receive the respective coils (not shown)

In Fig. 3 a similar arrangement as shown in Fig. 2a is being displayed but here with an Evans core which comprises two neighboring cores being enveloped by a third core which is clasping the two cores commonly.

In Fig. 4a a similar arrangement is shown as already in Fig. 2a but here with a trapezoidal core loop 28 on a trapezoidal mandrel 30 whereas the rest of the arrangement is the same as with that shown in Fig. 2a. A laser 22 is positioned below of the core 28 and its beam 24 is directed to the lower front of the core 28 where the inserts 21 have been introduced between the layers of the ribbons as illustrated before.

In Fig. 4b a staggered step-lap rectangular core loop 28 after re-lacing is shown. As shown the formerly cut parts of the core which corresponds to the base side in Fig. 4a, i.e. the longer of both short sides, have been re-laced i.e. reunited and finally the upper and the lower short sides have the same length thus the core is rectangular.

According to the invention it is possible to provide cuts different from straight cuts thus a better magnetic flux as well as overlapping of the cut ribbons is achieved when re-lacing their ends.

List of References

10	core
12	core leg
14	coils
16	core loop
18	core support
20	core legs, unlaced ribbons
21	inserts
22	laser
24	laser beam
26	mandrel
28	trapezoidal core
30	trapezoidal mandrel

Claims

1. Method for manufacture of a transformer core made of ferromagnetic material, such as amorphous metal or silicon iron, which is provided as a single ribbon layer or as multiple ribbon layers,
characterized by the following steps
 - a) the single ribbon layers or bundle of ribbon layers of ferromagnetic material, such as amorphous metal or silicon iron, are continuously wound into loops, whereas the shape of the core loops is effected by means of an appropriate mandrel to be directly formed into its final shape;
 - b) the single or multiple ribbon layers of the loops are being cut in that
 - a mechanical device or a laser is used for cutting, allowing fast and precise cutting of the ribbons, and in that
 - all ribbons of the loops are cut at at least one position along the circumference of each ribbon layer.
2. Method according to claim 1, characterized in that the mandrel is removed and the core is temporarily fixed in order to keep its shape by means of a mold or any appropriate support.
3. Method according to claim 1 or 2, characterized in that the core is being annealed whereas the loop is closed.
4. Method according to one of the preceding claims where the core is being partly or completely coated with resin or a different polymeric material in order to stabilize its structure mechanically.
5. Method according to at least one of the preceding claims characterized in that during the winding process stripes of different material can locally be inserted into the winding whereas the cuts are made at the position of the inserts..
6. Method according to claim 5 characterized in that the inserts are being introduced after each ribbon layer or after a bundle of layers in order to limit the depth of the cuts.

7. Method according to claim 5 or 6 comprising characterized in that the inserts are being displaced, allowing a step-butt configuration.
8. Method according to at least one of the claims 5 to 7 characterized in that the inserts consist of amorphous metal, Si-steel, other metal foils, or polymeric foils e.g. made of PTFE.
9. Method according to at least one of the preceding claims characterized in that the winding axis has a horizontal or vertical or some other direction.
10. Method according to at least one of the preceding claims characterized in that in case of Evans cores, the outer loop can directly be wound on the two inner loops.
11. Method according to at least one of the preceding claims characterized in that for the positioning of the core/loop for cutting them to the appropriate length the laser is being placed below it in order to allow the ribbon layers open up (unlace) by gravity.
12. Method according to at least one of the preceding claims characterized in that for displacing the position of the cuts, either the core or the laser is being displaced, the direction is adjusted or the laser beam is displaced by at least one mirror.
13. Method according to at least one of the preceding claims characterized in that other than straight cuts are being done, e.g. a wave-shaped cut, in order to improve the magnetic flux and reduce losses and excitation current.
14. Method for manufacture of a transformer having a core made of amorphous metal or other ferromagnetic material like silicon steel, according to at least one of the preceding claims characterized by the following steps
 - a) after the winding of the ribbons consisting of ferromagnetic material, such as amorphous metal or silicon iron, has been finished the core is provided with supports in order to maintain the shape of the core and one side of the core loop is being cut by means of laser cutting whereas prior to or after the cutting of the core an annealing procedure takes place;

- b) after the annealing procedure the cut ends of the respective core loop are bent up so that the core legs are accessible;
 - c) then at least the lower part of the core comprising the core legs and its connecting part is coated with resin or a different polymeric material in order to make it mechanically stable,
 - d) on at least one core leg at least one transformer coil is shifted and
 - e) then the opened core is re-laced and the not yet coated part of the core is coated.
15. Transformer comprising a core manufactured according to the method being claimed by at least one of the preceding claims.

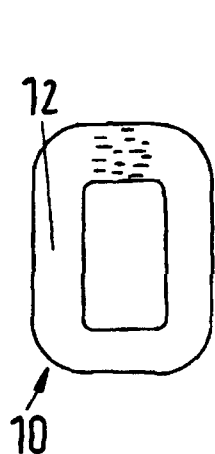


Fig. 1a

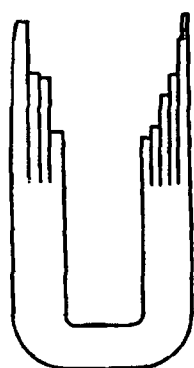


Fig. 1b

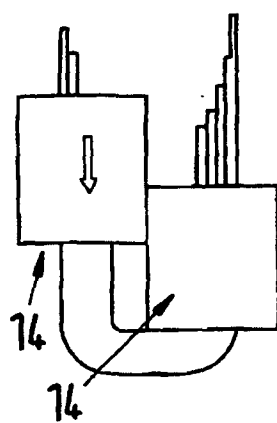


Fig. 1c

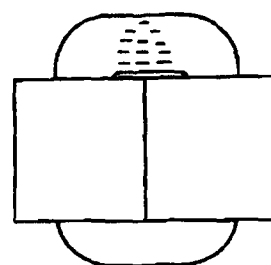


Fig. 1d

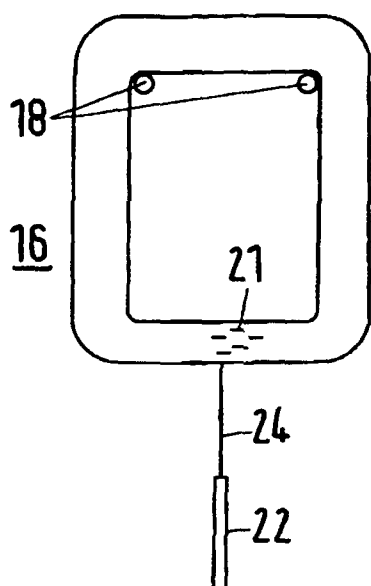


Fig. 2a

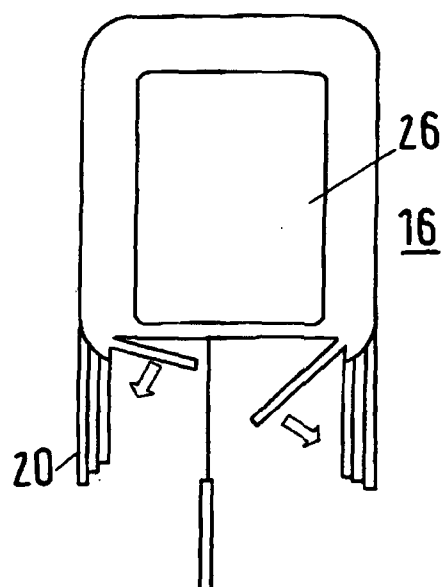


Fig. 2b

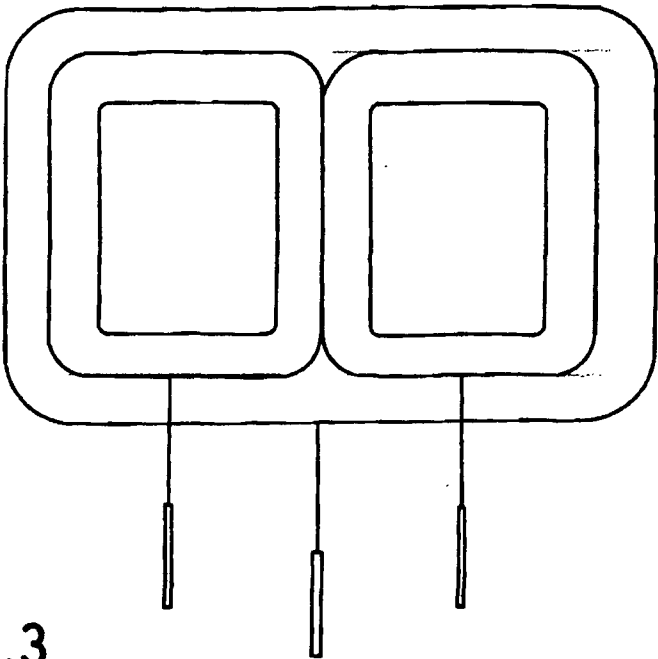


Fig.3

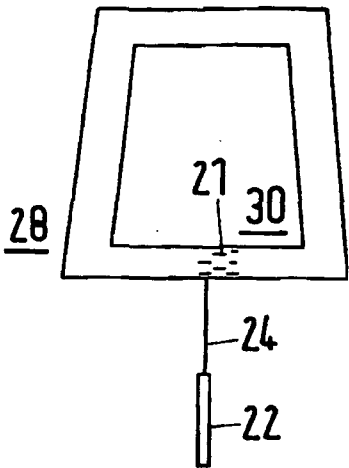


Fig.4a

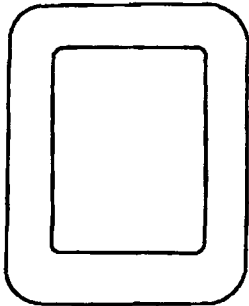


Fig.4b

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/002349

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01F41/02 H01F27/30
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 709 471 A (VALENCIC MILAN D [US] ET AL) 1 December 1987 (1987-12-01) column 7, paragraph 2 - column 10, paragraph 5; claims 1,10,19,21,28; figures 9,19	1-15
A	----- US 4 972 168 A (GRIMES FRANK H [US] ET AL) 20 November 1990 (1990-11-20) claim 1; figure 2	1-15
A	----- US 2002/194723 A1 (SHEN JINXING [DE] ET AL) 26 December 2002 (2002-12-26) claims 1,4	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search

31 May 2011

Date of mailing of the international search report

08/06/2011

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Authorized officer

Primus, Jean-Louis

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2011/002349

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