(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 288 976 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
05.03.2003 Bulletin 2003/10

(51) Int Cl.7: **H01F 27/245**, H01F 41/02

(21) Application number: **01830558.1**

(22) Date of filing: **30.08.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

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(54) Ferromagnetic nucleus, particularly for transformers or the like, and process for manufacturing the same

(57) A core of ferromagnetic material for transformers and the like is provided which is made up of a pack of laminations (5) and comprises a side surface (6) having a continuous conformation without sharp corners even at regions (6a) formed by longitudinal edges (5a) of the laminations (5).
Also provided is a process for manufacturing cores of the above described type consisting in cutting out from a metal sheet, a plurality of laminations (5) of same size, carrying out superposition and irremovable union of the laminations so as to form a pack, and shaping by a working involving material removal, the regions of the side surface of the lamination pack formed with the longitudinal edges of said laminations.

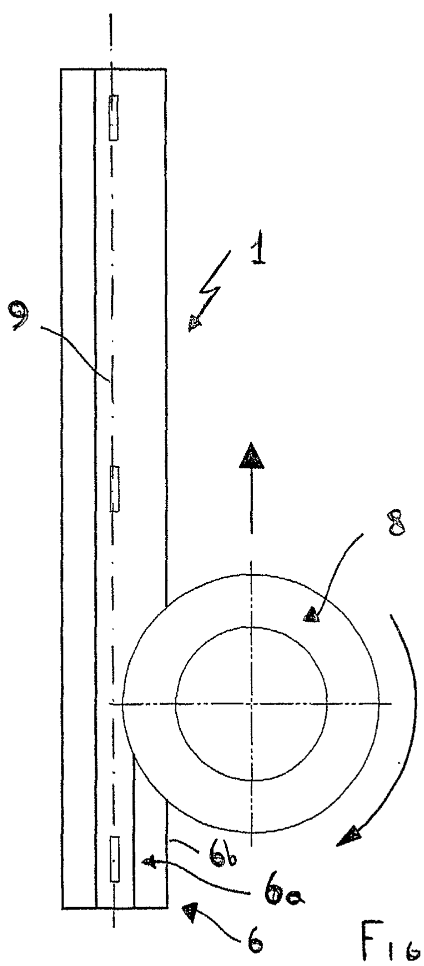

FIG. 6

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Description

[0001] The present invention relates to a nucleus or core of ferromagnetic material, particularly for transformers and similar apparatus and to a process for manufacturing the same, the nucleus being of the type made up of a pack of laminations joined together in an irremovable manner and comprising a side surface consisting at least partly of longitudinal edges of said laminations and designed to be surrounded by the coaxial windings of a transformer.

[0002] It is known that cores of ferromagnetic material are used in transformers for insertion in the primary and secondary windings of the latter to reduce leakage of the magnetic flux as much as possible.

[0003] Particularly known are applications for high voltage coils in ignition systems for car engines in which voltages of very high values are reached, in the order of 40-50 kV. In these applications cores have an elongated shape i.e. they are substantially made up of an element in the form of a rectilinear bar comprising a side surface designed to be surrounded, possibly by interposition of an appropriate insulating sheath (or the like), by the primary and secondary windings.

[0004] In order to obtain good performance from an electric/magnetic point of view, it is necessary that the empty space at the inside of the winding which is close to the core should be filled with ferromagnetic material as much as possible. Practically the core is required to have a side surface substantially conforming in shape to the inner surface of the coil surrounding it.

[0005] A first known technique involves use of cores obtained by die-casting of composite materials, i.e. consisting of particles of ferromagnetic material and a binder. These cores however, while enabling the conformation of the windings at the inside of which they are fitted to be followed in a precise manner, have a drawback, i. e. they do not possess crystals of ferromagnetic material suitably oriented in the direction of the magnetic flux and therefore do not enable achievement of a high performance in the transformer operation.

[0006] In addition, due to the necessary presence of a binding material, not provided with magnetic properties, there is a further decay in the winding performance.

[0007] Another known technique provides for each core to be made up of a pack of laminations obtained by a rolling operation in the direction that the magnetic flux must have.

[0008] The laminations, generally of a thickness of some tenths of a millimetre, are cut to the required length for the core but with different widths so that they can be superposed to form a pack the cross section of which widens in the middle and gets narrower at the two external laminations in order to be able to obtain a contour surface most approaching a cylindrical shape like that of the space into which it is to be inserted. In addition the laminations are jointed together in an irremovable manner by welding or other connection processes.

[0009] Practically, cores obtained following the above described technique have a side surface at the longitudinal edges of the laminations which has a discontinuous conformation since it is made up of the steps formed by the sharp corners of the longitudinal edges themselves.

[0010] Said core lamination packs first of all have the drawback that they do not properly match the shape of the inner surface of the winding in which they are to be inserted and therefore, since they do not completely occupy the empty space defined by said winding, they do not allow maximization of the electric performance of the transformer.

[0011] In addition, since the outer surface of said cores is at least partly formed with sharp corners, the cores can be the place where, above all in the presence of high voltages of the windings disposed around them, dangerous discharges occur due to the so-called "point effect" caused by the sharp edges themselves, and therefore the voltage that can be obtained on the secondary winding of the transformer must necessary be limited.

[0012] Under this situation the technical task underlying the present invention is to devise a core of ferromagnetic material for transformers and similar apparatus and a process for manufacturing the same which are capable of substantially obviating the mentioned drawbacks.

[0013] Within the scope of this technical task it is an important aim of the invention to devise a core that not only enables the typical performance of the cores in the form of lamination packs to be reached but also allows improvement of same by optimizing filling of the space in which the core is to be inserted and avoiding the risk of undesirable discharges, even in the presence of high voltages in the winding surrounding it.

[0014] Another important aim of the invention is to devise a process for manufacturing cores of ferromagnetic material made up of lamination packs of quick and cheap accomplishment.

[0015] It is a further aim to devise a process enabling manufacture of cores of ferromagnetic material formed with laminations fixedly joined together to create perfectly shaped packs in compliance with the specific application requirements.

[0016] The technical task mentioned and the aims specified are substantially achieved by a core of ferromagnetic material and a process for manufacturing the same that are characterized in that they comprise one or more of the technical solutions hereinafter claimed.

[0017] Description of a preferred but not exclusive embodiment of a core of ferromagnetic material in accordance with the invention is now given, by way of non-limiting example, with the aid of the accompanying drawings, in which:

- Fig. 1 is a longitudinal section of a portion of an ignition system for a car engine in which a core of ferromagnetic material in accordance with the invention is inserted;

- Fig. 2 is a plan view of a lamination obtained by cutting-out in a first step of a process for manufacturing the core referred to in Fig. 1;
- Fig. 3 is an elevation front view of a pack of laminations jointed together in the second step of the process;
- Fig. 4 is a plan view of the lamination pack shown in Fig. 3 highlighting the clenching points;
- Fig. 5 is an enlarged sectional view taken along line V-V of two laminations of the pack shown in Fig. 3;
- Fig. 6 is a plan view of the lamination pack in Fig. 4 submitted to the third step of the process consisting of a milling working;
- Fig. 7 is an elevation front view of the pack in Fig. 6 during said milling step; and
- Figs. 8 and 9 show possible alternative cross sections of the core being the object of the invention; and
- Fig. 10 shows a possible alternative longitudinal section of the core being the object of the invention.

[0018] With reference to the drawings, the core of ferromagnetic material in accordance with the invention is generally identified by reference numeral 1.

[0019] In the application given by way of example in Fig. 1 it is laterally surrounded by an insulating sheath 2 around which a first electric winding 3 is disposed followed, more externally, by a second winding 4.

[0020] Core 1 (an elongated body having a longitudinal axis of substantially I-shaped conformation) is formed of a pack of laminations 5 preferably joined together in an irremovable manner and comprises a side surface 6 at least partly made up of longitudinal edges 5a of said laminations 5. In an original manner, the side surface 6, designed to be surrounded by the coaxial windings 3 and 4, has at least one portion of continuous conformation, i.e. without sharp corners even at the regions 6a formed with the longitudinal edges 5a of the laminations 5.

[0021] More specifically, in the embodiment shown in Figs. 6 and 7, said regions 6a are convex and in the form of an arc of a circle. They connect two opposite flat faces 6b defined by the two externally-disposed laminations.

[0022] In other words, the convex regions 6a seen in cross section show a curved profile, preferably although not necessarily of a constant radius.

[0023] Looking in more detail at the cross sections shown in Figs. 7, 8 and 9 it is possible to see that laminations 5 have curved longitudinal edges 5a; a predetermined number of laminations in succession (but preferably all of them) defining said pack have longitudinal edges contiguously and mutually linked up.

[0024] As can be seen, in fact, the corners bounding the longitudinal edges of each lamination are directly disposed close to and in contact with the corresponding corners of a preceding lamination and of a following lamination.

[0025] This particular geometric configuration enables the presence of sharp-cornered points or at all events discontinuities in the cross-section profile to be avoided.

[0026] It is apparent that, although the preferred cross section is the one shown in Fig. 7, it will be also possible to contemplate accomplishment of cores of ferromagnetic material having a different, both symmetric and asymmetric, cross section (Figs. 8 and 9, respectively).

[0027] It is also clear that the present invention contemplates a working possibility not only on the section but also along the longitudinal extension axis of the core.

[0028] In particular, cores tapering in the direction of the longitudinal axis 9 can be obtained, as in the example shown in Fig. 10.

[0029] Also provided is the presence of engagement means to enable a coherent lamination pack to be obtained; in particular the mutual engagement means will be arranged in such a manner that a tight connection between the laminations forming the pack is allowed.

[0030] Said engagement means is preferably defined by fitting expansions 7b formed in a lamination 5 and respective coupling seats or recesses 7a formed in the following lamination.

[0031] The invention also relates to a new process being an integral part of the present patent application as well, and adapted to manufacture cores consisting of lamination packs of the above described type.

[0032] The process first of all comprises a first arrangement step, consisting in cutting out from a metal sheet for example, a plurality of laminations 5 of any sizes (for example, all having the same width and the same length corresponding to the final length of the core to be manufactured).

[0033] Subsequently the process involves a second forming step in which the lamination pack is obtained by superposition and irremovable union of said laminations. Obviously, the number of the required laminations to be superposed and joined together for reaching the final height of the core depends on the thickness of the metal sheet used.

[0034] Finally a third shaping step is provided which consists of a working involving material removal from the regions of the side surface of the lamination pack formed with the longitudinal edges 5a of said laminations, so that said regions may take a continuous conformation, i.e. devoid of sharp corners and in the form of an arc of a circle, for example.

[0035] In more detail, the second forming step for obtaining the lamination pack is carried out by successive operations on each individual lamination and it consists in superposing each lamination (obviously with the exclusion of the first lamination) on the one previously laid down, clenching to the free face of said lamination, the mating face of the lamination submitted to the connecting operation.

[0036] Advantageously clenching of each lamination is obtained by punching of same at least at two points, three points for example, spaced apart from each other and defining corresponding attachment regions 7 (see Fig. 4).

[0037] Punching at said attachment regions 7 is adapted to plastically deform each individual lamination forming a recess or coupling seat 7a on the free face thereof which corresponds to a fitting expansion 7b to be inserted in the recess of the lamination previously arranged (see Fig. 5).

[0038] Practically expansions 7b penetrate by tight fit into the recesses 7a causing a steady and safe connection between the laminations.

[0039] The third step of shaping the side surface 6 of the lamination pack is advantageously carried out by a milling operation consisting of one or more passes oriented in the extension direction of the longitudinal edges 5a of laminations 5 (see Fig. 6; axis direction 9).

[0040] The milling cutter 8 to be used is preferably a concave-profile cutter and during working it enables the laminations to be pressed against each other preventing them from being submitted to separation forces and also to possible deformations at the edges.

[0041] The invention achieves important advantages.

[0042] In fact, the cores made up of lamination packs in accordance with the invention enable performance of the transformers for which they are used to be maximized because, first of all, they have an outer side surface substantially conforming in shape to the windings into which they are inserted so that practically at the inside of said windings, regions unfilled with ferromagnetic material do not exist.

[0043] In addition, the conformation continuity of the side surface of the cores in accordance with the invention eliminates the presence of sharp corners and therefore mostly reduces any possibilities of discharges caused by the "point effect", even in the case of very high voltages generated in the windings.

[0044] It should be recognized that in the process for manufacturing cores in accordance with the invention the laminations are required to be cut of same sizes and therefore the cutting-out operation is particularly cheap.

[0045] In addition, the process involves steady assembling of the lamination packs with a mere punching operation, so that production costs and times are very reduced.

[0046] In particular it will be understood that material removal by milling, which operation is suitable to determine shaping of the side surface of the cores, is particularly advantageous because it can be easily adapted, by conveniently changing the tool, to make cores formed of lamination packs having the conformation required for each specific application, for instance with tapering shapes at the ends or any other modification not only of the transverse profile but also of the longitudinal one.

Claims

1. A core of ferromagnetic material, particularly for transformers and similar apparatus, of the type made up of a pack of laminations (5) joined to each other preferably in an irremovable manner and comprising a side surface (6) at least partly consisting of longitudinal edges (5a) of said laminations (5) and designed to be surrounded by the coaxial windings (2, 3) of a transformer,
   characterized in that said side surface (6) has at least one portion with a continuous conformation devoid of sharp corners at the regions formed with a predetermined number of longitudinal edges (5a) of the laminations (5).

2. A core as claimed in claim 1, **characterized in that** said side surface (6) comprises at least two convex regions (6a) formed with said longitudinal edges (5a) of the laminations (5).

3. A core as claimed in claim 2, **characterized in that** said side surface (6) comprises two opposite flat faces (6b) defined by the two outermost laminations of said pack and **in that** said convex regions (6a) are in the extension of said opposite flat faces (6b).

4. A core as claimed in claim 2, **characterized in that** said convex regions, seen in cross section, have a curved profile preferably of a constant radius.

5. A core as claimed in anyone of the preceding claims,
   characterized in that said laminations (5) have curved longitudinal edges (5a), a predetermined number and preferably all of the laminations (5) disposed in succession in said pack having longitudinal edges contiguously and mutually linked up.

6. A core as claimed in anyone of the preceding claims,
   characterized in that it has mutual-engagement means arranged to enable a link between the laminations forming the pack, said engagement means being preferably defined by fitting expansions formed in a lamination and by respective coupling seats formed in the subsequent lamination.

7. A core as claimed in anyone of the preceding claims,
   characterized in that it is an elongated body having a longitudinal axis substantially of an I-shaped conformation.

8. A process for manufacturing a core of ferromagnetic material (1), particularly for transformers and similar apparatus, the core consisting of a pack of laminations (5) and comprising a side surface (6) de-

signed to be surrounded by the coaxial windings of a transformer, said side surface (6) in turn comprising at least two regions (6a) formed with longitudinal edges (5a) of the laminations (5),
characterized in that in consists in:

- arranging a plurality of laminations, preferably obtained by cutting-out from a metal sheet,
- carrying out superposition and union of said laminations so as to form a pack of same,
- shaping by at least one working involving material removal, at least one of said two regions (6a) of said side surface (6) formed with the longitudinal edges (5a) of the laminations (5) so that said regions will have at least one portion with a continuous conformation devoid of sharp corners.

9. A process as claimed in claim 8, **characterized in that** said working involving material removal is defined by a milling operation carried out in the extension direction of said longitudinal edges (5a) of the laminations (5).

10. A process as claimed in claim 9, **characterized in that** said milling operation is carried out by at least one concave-profile milling cutter.

11. A process as claimed in claim 8, **characterized in that** said operations involving superposition and irremovable union of the laminations are carried out by operating in succession on each individual lamination, and **in that** said irremovable union is obtained by clenching of the face of each lamination with the mating free face of the previously arranged lamination.

12. A process as claimed in claim 11, **characterized in that** said clenching of each individual lamination is obtained by punching of the lamination itself at least at two points spaced apart from each other and defining corresponding attachment regions (7).

13. A process as claimed in claim 12, **characterized in that** said punching is adapted to plastically deform each lamination in said attachment region (7) forming a recess or coupling seat (7a) in the free face of said lamination and a corresponding fitting expansion (7b) in the opposite face, which expansion is inserted in the recess (7a) of the previously arranged lamination.

14. An ignition coil, to be used in particular in ignition systems for internal combustion engines, comprising at least one core in accordance with anyone of claims 1 to 7.

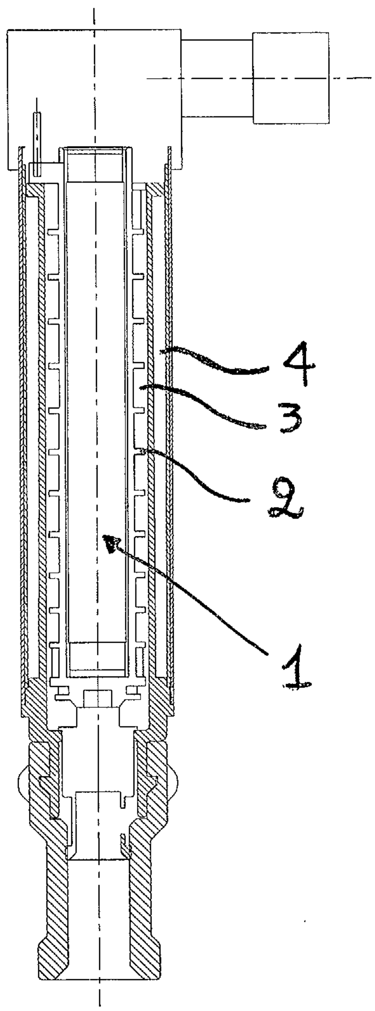

Fig. 1

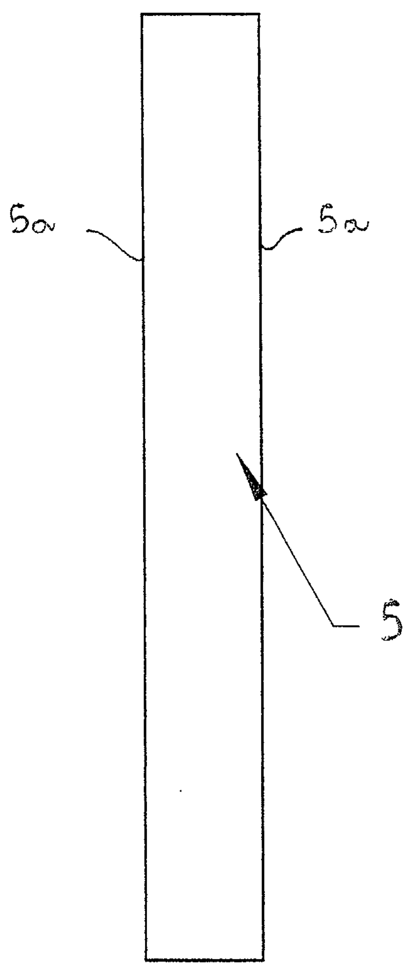

Fig. 2

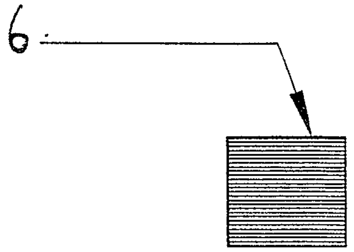

Fig. 3

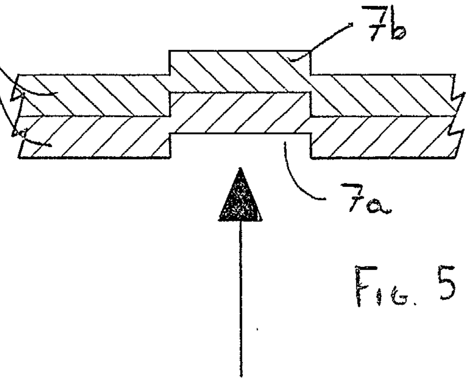

Fig. 5

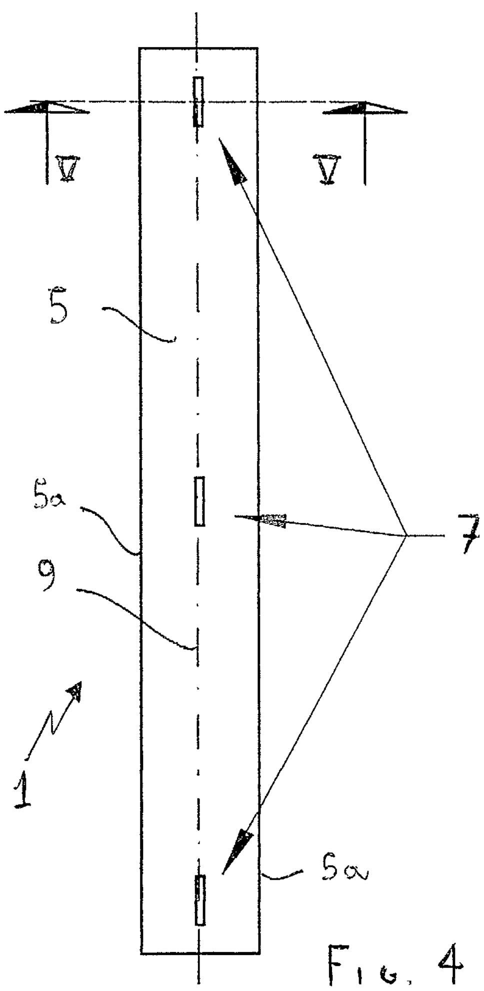

Fig. 4

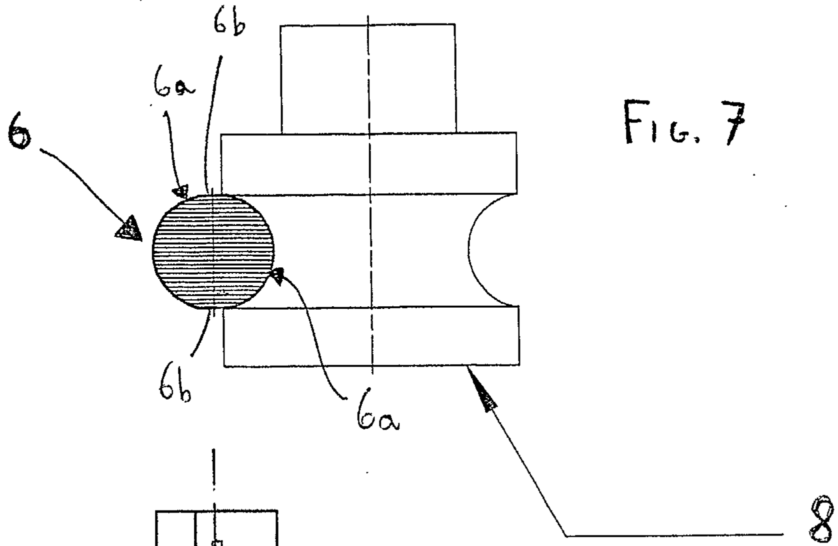

FIG. 7

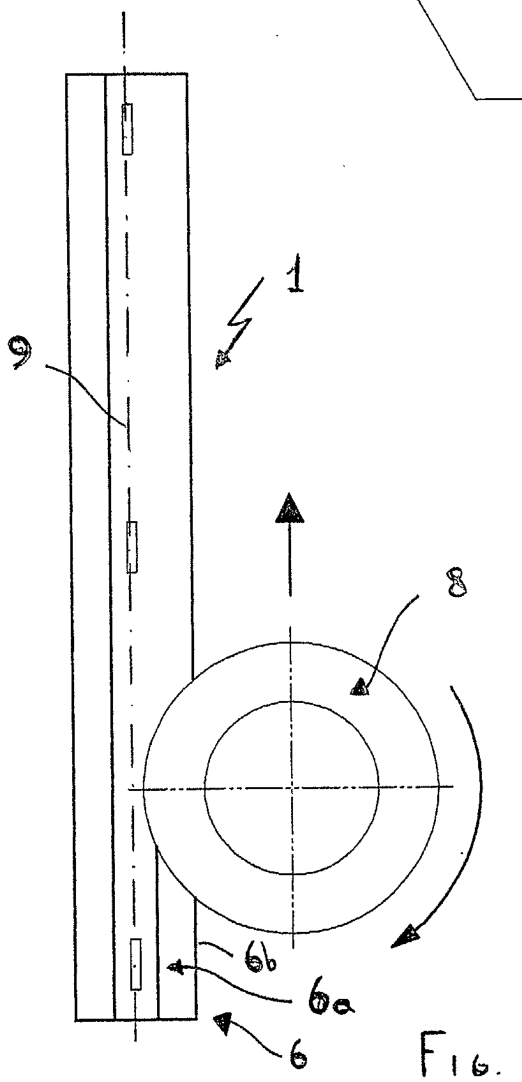

FIG. 6

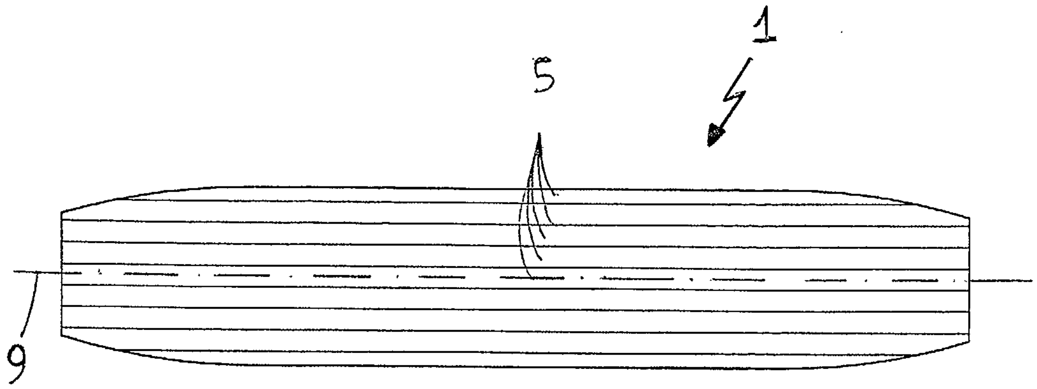

Fig. 10

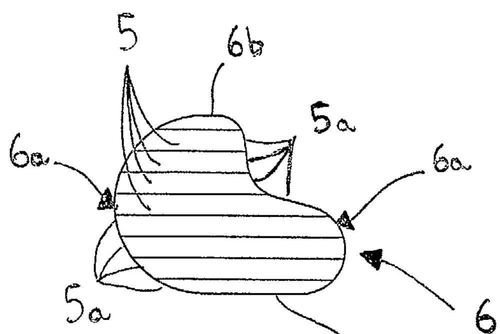

Fig. 9

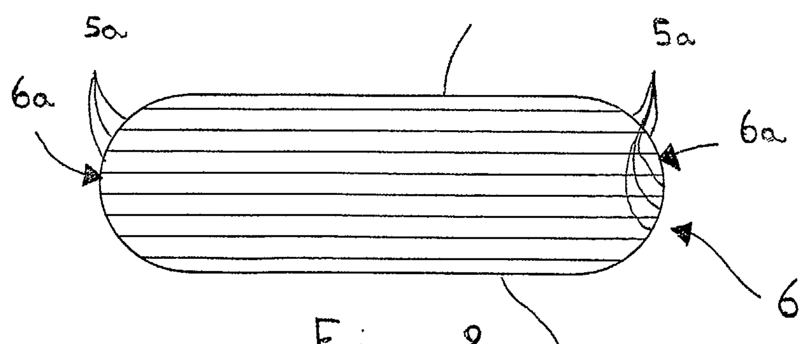

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 01 83 0558

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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

H01F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 January 2002	Vanhulle, R

CATEGORY OF CITED DOCUMENTS

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