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(54) **TRANSFORMER CORE**
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(73) Proprietor: **HÖGLUND, Lennart Harry Erik
S-582 62 Linköping (SE)**

(72) Inventor: **HÖGLUND, Lennart Harry Erik
S-582 62 Linköping (SE)**

(74) Representative: **Estreen, Lars J.F. et al
Kransell & Wennborg KB
P.O. Box 27834
115 93 Stockholm (SE)**

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Description

FIELD OF INVENTION

[0001] The present invention relates generally to transformer cores and especially to a transformer core comprising three legs and yoke parts connecting the legs.

BACKGROUND

[0002] Three-phase transformer cores are usually made of transformer plates cut to E I shape for small transformers and to rectangular plates, which are laid edge to edge, in larger transformers. They have the drawback that the magnetic field has to pass via edges from plate to plate and that the magnetic field must go an unnecessarily long way and not always along a magnetic orientation.

[0003] Designers of transformer cores have striven to obtain legs with an essentially circular cross-section because that gives the best efficiency of the final transformer. However, there is always a trade-off between efficiency and production requirements, leading to non-optimal transformer cores with non-circular legs.

[0004] Strip cores for three-phase transformers have hitherto been difficult to manufacture. The efficiency of the core can be increased by cutting strips to variable width and winding rings, which are given a circular cross-section for single-phase transformers and semicircular cross-section for three-phase transformers. This method results in a great deal of waste and the winding process is time consuming.

[0005] US 4,557,039 (Manderson) discloses a method of manufacturing transformer cores using electrical steel strips having approximately a linear taper. By selecting a suitable taper, a hexagonal or higher order approximation of a circular cross section for the legs of the cores is produced. However, the tapered strips are difficult and time-consuming to produce and the design is not well adapted to large-scale production.

[0006] In figs. 1a-c is shown a prior art three-phase transformer core according to Manderson, generally designated 10. The core has a general delta-shape, as is seen in the isometric view of fig. 1, with three legs interconnected by yoke parts. In fig. 1a, a cross-sectional view of the core is shown before final assembly. The core comprises three identical ring-shaped parts 12, 13, and 14, the general shape of which appears from fig. 1. Each ring-shaped part fills up one half of two legs with hexagonal cross-sections, see fig. 1a, thus totalling the three legs of a three-phase transformer. The ring-shaped parts are initially wound from constant width strips to three identical rings 12a, 13a, 14a with rhombic cross-sections comprising two angles of 60 degrees and two angles of 120 degrees. These rings 12a-14a constitute the basic rings. The orientation of the strips also appears from figs. 1a and 1b.

[0007] Outside of the basic ring in each ring-shaped

part there is an outer ring 12b, 13b, 14b of a regular triangular cross-section. The outer rings are wound from strips with constantly decreasing width.

[0008] When the three ring-shaped parts 12-14 are put together, see fig. 1b, they form three hexagonal legs on which the transformer windings are wound.

[0009] A drawback with this solution is that every size of transformer requires its own cutting of the strips. Also, the outer rings 12b-14b are made of strips with decreasing width, leading to waste and it also makes the transformer according to Manderson difficult to manufacture.

[0010] Three-phase transformer cores are also described in the following documents: SE 163797, US 2,458,112, US 2,498,747, US 2,400,184, US 2,544,871, US 2,401,952 and US 2,431,155. However, the cores described in these documents do not overcome the above-mentioned problems.

OBJECT OF THE INVENTION

[0011] An object of the present invention is to provide a transformer core wherein the energy losses are minimised.

[0012] Another object is to provide a transformer core, which is easy to manufacture and avoids material waste.

[0013] Another object is to provide a method of manufacturing a transformer that is well adapted for large-scale production.

SUMMARY OF THE INVENTION

[0014] The invention is based on the realisation that a transformer core with one or more regularly multi-edged legs with more than four edges can be wound of strips of material with constant width.

[0015] According to the invention there is provided a transformer core, comprising three legs and yoke parts connecting the legs, wherein the cross-section of the legs is the same and in the form of a regular polygon with more than four edges, characterised in that the core is solely made up of rings rolled from strips of constant width, where different rings may have different widths and each of the rings make up part of two of the legs.

[0016] Further preferred embodiments are defined in the dependent claims.

BRIEF DESCRIPTION OF DRAWINGS

[0017] The invention is now described, by way of example, with reference to the accompanying drawings, in which:

fig. 1 is an isometric view of a prior art three-phase transformer core made of rings with rhombic and triangular cross-sections;

figs. 1a and 1b are transverse cross-sections of the core shown in fig. 1 before and after assembly, re-

spectively;

fig. 2 is an isometric view of a three-phase transformer core according to the invention with legs with hexagonal cross-sections;

figs. 2a and 2b are transverse cross-sections of the core shown in fig. 2 before and after assembly, respectively;

figs. 3a and 3b are transverse cross-sections of an alternative three-phase transformer core with legs with hexagonal cross-section before and after assembly, respectively;

Fig. 4 is an isometric view of a three-phase transformer core with octagonal legs;

Fig. 4a is a transverse cross-section of the core shown in fig. 4;

Fig. 5 is a cross-section of a transformer leg with ten edges;

Fig. 6 is a cross-section of a transformer leg with twelve edges;

Figs. 7-9 show an arrangement for influencing the leakage inductance and the harmonics in a three-phase transformer;

Fig. 10 is a transverse cross-section of a three-phase transformer core with specially shaped yoke parts for improving the magnetic flux;

Fig. 11 shows a three-phase transformer core with lined up legs;

Figs. 12-14 show one-phase transformer cores according to the invention; and

Figs. 15-17 show further improvements of the shape of the transformer core cross-section.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Preferred embodiments of a three-phase transformer core according to the invention will now be described.

[0019] Fig. 1 has already been discussed in connection with prior art and will not be explained further.

[0020] In fig. 2 is shown a three-phase transformer core according to the invention, generally designated 20. In its general shape it is similar to the prior art transformer core shown in fig. 1 with a general delta-shape but is designed in an entirely different way.

[0021] The core is made up of three ring-shaped parts 22, 23, 24 comprising several rings. These come in two

widths, broad or narrow wherein the narrow rings are made up of strips of half the width of the broad rings. Also, they come in two heights, low or high wherein the low rings have half the height of the high rings. Unless otherwise stated, these definitions will be used throughout this description. The strips are preferably made of transformer plate.

[0022] Each of the ring-shaped parts 22-24 comprises a broad high basic ring 22a-24a, respectively, similar to those described with reference to fig. 1. Thus, these rings form in pairs four of the sides in the hexagonal legs. The remaining rhombs in the legs are built in different ways, see figs. 2a and 2b.

[0023] In the first leg 25 in the background, the additional rhombic cross-section is composed of two rhomboids. The first one, designated 24b and belonging to ring-shaped part 24, is a broad low ring. The second one, designated 22b and belonging to ring-shaped part 22, is a narrow high ring.

[0024] In the second leg 26 to the right in fig. 2, the additional rhombic cross-section is composed of one rhomboid and two rhombs. The rhomboid is filled by the narrow high ring 22b belonging to the ring-shaped part 22.

[0025] The rhombs are filled by two narrow low rings 23b, 23c belonging to the ring-shaped part 23.

[0026] In the third leg 27 to the left in fig. 2, the additional rhombic cross-section is also composed of one rhomboid and two rhombs. The rhomboid is filled by the broad low ring 24b belonging to the ring-shaped part 24. The rhombs are filled by two narrow low rings 23b, 23c belonging to the ring-shaped part 23. The reason that the ring-shaped part 23 comprises two low narrow rings instead of one larger ring is that this larger ring can not be both narrow and high, as required in the left leg 27, and broad and low, as required in the right leg 26. Thus, instead two narrow low rings are used.

[0027] All upper or lower yokes connecting the legs 25-27 have different shapes but all are built from one basic ring with a large rhombic cross-section plus one ring with a rhomboidal cross-section or two rings with a small rhombic cross-section. This gives all yokes the same total cross-section area.

[0028] The rhombic space outside of the basic rings could of course be filled in accordance with a couple of basic principles. A second embodiment will now be described with reference to figs. 3a and 3b. The core, generally designated 30, has the same general shape as the first embodiment described above. However, in this embodiment the core comprises three identical ring-shaped parts 32-34, of which the rightmost one 32 will be described. The ring-shaped parts 32-34 are similar to the part 23 described in connection with fig. 2. In the first leg 35, part 32 comprises two narrow low rings 32b, c wherein ring 32c is wound outside of ring 32b. In the second leg 36, part 32 has the two rings 32b, 32c placed one beside the other, see fig. 3a.

[0029] The two other parts 33, 34 are identical to the

first one 32. Thus, the production of the core can as a rule be simplified, depending on the production volume, because all three ring-shaped parts 32-34 can be made from the same mould.

[0030] A further possibility is to make broad low rings and turn the leg parts 60 degrees, forcing a corresponding bending of the yoke parts. The yoke parts then require more space and the bending is not so easy to effect. Making narrow high rings and turning and bending as mentioned is also possible, but difficult. Additional variants, including those with smaller divisions, are also possible.

[0031] A core with octagonal legs, generally designated 40, will now be described with reference to figs. 4 and 4a. In an octagonal cross-section, see e.g. the back leg 45, the sides turn 45 degrees, which means that they have a relative angle of 135 degrees to each other. Three rhombs, each with an angle of 45 degrees, thus get space in the innermost edges of the legs of the core. Outside of these rhombs, two squares are filled by rings with quadratic cross-sections. Finally, a rhomb fills the rest of the octagonal cross-section of the leg.

[0032] From these six cross-sections, three subsections compose the cross-section of a profiled ring going to the second leg 46. The remaining subsections compose the cross-section of a profiled ring going to the third leg 47. There is also a profiled ring connecting the second and third legs 46, 47.

[0033] The three profiled rings all contain two rings with equal leg parts. A first ring 42a, 43a, 44a has a rhombic cross-section and the yoke parts bent 15 degrees. A second ring 42b, 43b, 44b outside of the first ring is quadratic and follows the form of the first ring 42a-44a.

[0034] Using a solution from the embodiments with hexagonal legs described with reference to figs. 2 and 3, two outer rhombs compose the cross-section of an outer ring with the yoke parts bent 15 degrees. Alternatively, two inner rhombs compose an inner ring but bent 60 degrees. The next ring must now give an outer rhomb in one leg and an inner rhomb in the other leg and be bent 30 degrees. One type of profiled ring is to be preferred because it is difficult to bend a ring 60 degrees and one can not avoid a ring with both an outer rhomb and an inner rhomb.

[0035] In part 42, the third ring 42c has a rhombic cross-section in the leg parts and is placed outermost in the back leg 45 but inside the right leg 46. These rhombs of the leg parts are obtained by displacing the outer strips of the ring to the right at the right leg 46 and to the left at the back leg 45. Furthermore, the legs are turned asymmetrically 30 degrees and the yoke parts are bent accordingly. The ring is given such a circumference that it will lie outside of the other rings. The final result appears in fig. 4.

[0036] A 10-sided leg, generally designated 50, will now be described with reference to fig. 5. The profiled rings contain all four rings with equal leg parts. A first ring 50a, a second ring 50b and a third ring 50c with rhombic

cross-sections in their leg parts are attached to the 10-sided cross-section. Thus they have the angles 36, 72, and 108 degrees and their yoke parts bent 24 degrees. A fourth ring 50d having a rhomboid cross-section with the angle 36 degrees lies mainly upon the first ring 50a. Its leg parts are turned outwards 24 degrees, causing a 48 degrees bending of its yokes. The fourth ring also causes the yoke parts of the third ring 50c to make a larger bow to give space. A fifth ring 50e has a rhombic cross-section in its leg parts with the angle 144 degrees when it lies outside of the third ring 50c, but the ring has a rhombic cross-section with the angle 72 degrees when it lies outside of the fourth ring 50d. The yokes are bent only 12 degrees. The arrows in the figure indicate that the cross-sections 50e belong to different profiled rings. There will also be a channel 51 suitable for cooling the legs. In an alternative embodiment, the channel is filled with a ring. This is an advantage when the rings co-operate by letting the magnetic field go between them. The space can e.g. be disposed of in such a way that the upper part of the rings 50c obtains new rhombic cross-sections with the angle 72 degrees, causing the channels 52a and 52b to be formed. Further parts of ring 50c to the right can be pushed to ring 50e, which forms the spaces 53a and 53b.

[0037] It is possible to provide three-phase transformer cores with even more edges. Fig. 6 shows a 12-sided core, generally designated 60. The profiled rings are composed of four rings 60a-d with rhombic cross-sections with the angles 30, 60, 90, and 120 degrees, which are attached to the 12-sided cross-section and are turned 15 degrees. Inside of these rings there are two rings 60e, 60f with rhombic cross-sections with the angles 30 and 60 degrees, respectively, and turned outward 15 degrees. Attached to the fifth and sixth rings 60e, 60f there is space for a ring 60g with a rhombic cross-section with the angle 30 degrees turned outward 45 degrees. Its other leg part is a rectangle outside of the sixth ring 60f and turned outward 15 degrees. Upon the ring 60d there is space for a ring 60h with a rhombic cross-section with the angle 150 degrees and the other leg part is a rectangle attached to ring 60d and outside ring 60f. The whole cross-section is then filled. Yoke parts are separated by giving some wider bows to give space for other yoke parts.

[0038] The good properties of these transformer cores can be made even better for some transformer application, see fig. 7. The leakage inductance can easily be increased by an additional core 29 of strips between the primary and secondary windings of the transformer. The strips are brought together at the top and bottom. The strips can be spread around the entire primary winding or be concentrated to one place, making the secondary winding eccentric.

[0039] The non-linear magnetic properties of iron result in harmonics in the magnetic fields, voltages and currents.

[0040] An additional leg placed in the centre of the core

will not get any magnetic field under perfectly symmetrical and distortion-free three-phase conditions. Common components in the phase voltages, like the third harmonics, will be influenced by a centre leg.

[0041] Also a combination of strips between the windings and a centre leg is possible.

[0042] In one embodiment, the centre leg is made of three rectangular poles 80 from strips given a height three times the width, laid on each other to a quadratic cross-section, see fig. 8. This is preferably triangular and a custom-made solution contains poles with a rhombic cross-section, of which three are put together to form a packet with the strip edges toward each other in a wave form, see fig. 9. Three packets are put together with small distances to form a leg with a cross-section approximating a triangle. The ends of the poles are bent outward to reach the yokes. To make the bends possible spacers between the poles are necessary. The spacers do not influence the magnetic properties because one pole from each packet 91a-c; 92a-c; 93a-c is bent to each yoke. Also the strips are, at least on one side, parallel to the spacers.

[0043] A rod, wound of strips in spiral form or as coils, is useful, especially if there are to be air gaps between the centre leg and the yokes. The spiral can be made wider at the ends to reduce the air gaps to the yokes.

[0044] The flexibility of building cores like this is good and is shown in fig. 10. The figure shows the core described in connection with fig. 4. A major part of the magnetic flux can pass from one profiled ring to another in the legs where they are touching each other. This enables the rotation of larger fluxes in the yoke triangle.

[0045] With the present invention, it is also possible to provide a three-phase transformer core with lined up legs. This has the advantage that the transformer is narrower than with the delta shaped core. This type of transformer is ideal for placement on e.g. train wagons.

[0046] Fig. 11a shows the transverse cross-section of a transformer with octagonal legs. All legs comprise four rhombs with an angle of 45 degrees and two squares. Rings running between adjacent legs are shown in the figure while those running between the outer legs are almost entirely hidden.

[0047] In order to make transformer cores of this kind, the leg parts must be bendable and that the yoke parts can be bent and pass each other. There are several solutions, of which one is shown in the figure. The leg parts of the rings are bent outward and the yoke part inward or vice versa. The shape of the yoke parts is limited by the limited possibilities of plastic deformations but otherwise the yoke parts can have any shape. The principle shown in fig. 11 is to have sharp bends and straight yoke parts.

[0048] The rings can also be placed on each other giving rounded bends in order to save material.

[0049] The yokes between the left leg 115 and the centre leg 116 are built up of a ring 112a with a rhombic cross-section in the leg part, a ring 112b with a square

cross-section and both bent 22.5 degrees and a rhombic ring 112c turned 67.5 degrees in the leg parts. The rings 112a and 112b fit into the octahedrons close to the yoke side while the ring 112c fits into the opposing side.

[0050] The yoke between the centre leg 116 and the right leg 117 can only be placed in the centre leg in the remaining positions: 114a-c. The cross-sections of the left and right legs 115, 117 are mirror images to the centre leg 116 so that the rings running in the centre leg are symmetric. The inner rings 114a, 114b have their closest positions in the right leg 117. However, the ring 114c with a square cross-section in the leg parts runs to the closest square-shaped position in the right leg. The reason behind that is that the ring 113a with a square cross-section between the outer legs is in an outer position on the yoke parts already present in order to reach the left leg.

[0051] The turning of the yokes can be impossible to achieve. In an alternative embodiment, a heavily sloping fold is used instead. This is shown for the ring 114c having the shortest yoke. The fold starts at one end of the yoke and ends at the other end, marked by 118a for the lower yoke and 118b for the upper yoke in fig. 11. Also, the yokes can be subdivided into several narrow rings.

[0052] Also single-phase transformers will be more efficient if they are given polygonal cross-sections. Fig. 12 shows a transformer with an octagonal cross-section composed of rings with the same cross-sections as in the three-phase transformers but with the return loops going the closest way outside of the windings. The rings can be transposed and yet given an octagonal cross-section. A small reduction of the amount of plate can e.g. be obtained by looping up to the left of the ring looping rightmost in the figure. There must its cross-section be changed to a rhombic form close to rectangular form.

[0053] A core with two legs can be made from the three-phase designs by bending the rings from one leg together to form only one more leg. A core is shown in fig. 13 with an octagonal cross-section in its legs. The turning of three leg-parts is 45 degrees and the bending is 90 degrees. A ring with a rectangular cross-section and the two rings outside of that ring are not deformed. Cores with hexagonal legs need only three rings made of strips with the same width.

[0054] If that octagon edge where three rhomb edges meet, is put innermost in the core, the turnings will only be 22.5 degrees except for the rhomb in the middle, which must be turned 67.5 degrees. Replacing this rhomb with a ring, with steps approximating the rhomb, is more realistic and is shown in fig. 14. A further improvement is made by letting the strips reach the circle, thus increasing the total cross-section.

[0055] The segments outside of a polygonal leg can be filled by a thin rhombic ring of a strip with about half the width and the full height of the segment and wound to its total width. Folds in the strips along the middle of the rhomb as in fig. 15 make two sides to one flat side giving a triangle, the sides of which are in contact with the core. With about 2/3 width and 8/9 height, a fold at

the edge of the innermost strip makes a trapezoid cross-section as in fig. 16. The cross-section can also be rounded.

[0056] By means of strips of constant width the leg parts can be given a cross-section shape closer to the shape of a circle, see fig. 17, 17a and 17b. The right leg 172 in fig. 17 will be described as an example with reference to fig. 17a, wherein a transverse cross-section of that leg is shown. Innermost, there are rings 173 of e.g. 80% of full width and to a height of 9% of its width. There are three rings reaching a circumscribed circle, see fig. 17a.

[0057] Four of the six segments have been filled with magnetic material and strips outside of the assembled core can fill the other segments.

[0058] A ring 174 can be placed on the outer sides of the hexagons.

[0059] Another embodiment is shown in fig. 17b, wherein the ring 174 has been replaced by broader strips in the other rings.

[0060] Some of the advantages of the inventive transformer core have already been mentioned. Among the other advantages can be mentioned: lower no load losses, less weight, less volume, lower electrical leakage, a reduction of harmonics due to the symmetry of the phases of the three-phase transformer, easy maintenance etc.

[0061] Preferred embodiments of a transformer core according the invention have been described. The person skilled in the art realises that these can be varied within the scope of the claims.

Claims

1. A transformer core, comprising three legs and yoke parts connecting said legs, wherein the cross-section of said legs is the same and in the form of a regular polygon with more than four edges, **characterised in that** the core is solely made up of rings rolled from strips of constant width, where different rings may have different widths and each of said rings make up part of two of said legs.
2. A transformer core according to claim 1, **characterised in that** said legs have hexagonal cross-section.
3. A transformer core according to claim 2, **characterised in that** it comprises nine rings.
4. A transformer core according to claim 3, **characterised in that** it comprises three rings of a first width and a first height and six rings of a second width corresponding to half the first width and a second height corresponding to half the first height.
5. A transformer core according to claim 4, **characterised by**

a first (32), a second (33) and a third (34) ring-shaped part, wherein each ring-shaped part comprises a first ring (32a, 33a, 34a) wound from strips of a first width to a first height, the cross-sections of said rings being rhombic with two angles of 60 degrees, a second ring (32b, 33b, 34b) wound from a strip of a second width essentially corresponding to half the first width, to a second height essentially corresponding to half the first height, said second ring having rhombic cross-section and being positioned on said first ring (32a, 33a, 34a), a third ring (32c, 33c, 34c) wound from a strip of the second width to the second height, said second ring having rhombic cross-section and being positioned in one position on said first ring (32a, 33a, 34a) adjacent to said second ring and in another position on said second ring, said first, second and third ring-shaped part being assembled whereby a three-phase transformer core with three legs with hexagonal cross-sections is formed.

6. A transformer core according to claim 2, **characterised in that** it comprises seven rings.
7. A transformer core according to claim 6, **characterised by** a first (22a), a second (23a) and a third (24a) ring wound from strips of a first width to a first height, the cross-sections of said rings being rhombic with two angles of 60 degrees, said first, second and third rings forming yoke parts together forming a triangle, a fourth ring (24b) wound from a strip of said first width to a second height essentially corresponding to half the first height, said fourth ring having rhomboidal cross-section and being positioned on said third ring (24a), a fifth ring (22b) wound from a strip of a second width essentially corresponding to half the first width, to said first height, said fifth ring having rhomboidal cross-section and being positioned on said first ring (22a), a sixth ring (23b) wound from a strip of the second width to said second height, said sixth ring having rhombic cross-section and being positioned on said second ring (23a), and a seventh ring (23c) wound from a strip of the second width to said second height, said seventh ring having rhombic cross-section and being positioned on said second ring (23a) and on said sixth ring (23b), whereby a three-phase transformer core with three legs with hexagonal cross-sections is formed.
8. A transformer core according to claim 1, **characterised in that** said legs have octagonal cross-section.
9. A transformer core according to claim 8, **character-**

- ised by a first, a second, and a third profile ring, each comprising three rings (42a, 42b, 42c) with two leg parts and two yoke parts, wherein
 a first ring (42a) having rhombic cross-section in its leg parts with an angle of 45 degrees and with the yoke parts bent 15 degrees in such a direction that the outer side faces of its leg parts are moved towards each other,
 a second ring (42b) having quadratic cross-sections in its leg parts and being positioned on said first ring, and
 a third ring (42c) having rhombic cross-sections in its leg parts, a first leg part having 45 degrees lying mainly on said first ring (42a) and a second leg part having 135 degrees lying on said second ring (42b), said first, second and third profile rings being assembled whereby a three-phase transformer core with three legs with octagonal cross-sections is formed.
10. A transformer core according to claim 1, **characterised in that** said legs have a cross-section with ten edges.
11. A transformer core according to claim 10, **characterised by** a first, a second, and a third profile ring, each comprising five rings (50a-e) with two leg parts and two yoke parts, wherein
 a first ring (50a) having rhombic cross-sections in its leg parts with an angle of 36 degrees,
 a second ring (50b) having rhombic cross-sections in its leg parts with an angle of 72 degrees,
 a third ring (50c) having rhombic cross-sections in its leg parts with an angle of 108 degrees,
 a fourth ring (50d) having rhombic cross-sections in its leg parts with an angle of 36 degrees and lying mainly on the first ring (50a) and having its yoke parts turned outwards 24 degrees, and
 a fifth ring (50e) having rhombic cross-sections in its leg parts with an angle of 144 degrees when it lies on the third ring (50c) but rhombic cross-section with an angle of 72 degrees when it lies outside the fourth ring (50d), and a channel (51) suitable for cooling the leg outside of the fifth ring (50e),
 said first, second and third profile rings being assembled whereby a three-phase transformer core with three legs with ten-sided cross-sections is formed.
12. A transformer core according to claim 11, **characterised by** cooling channels (52a, 52b, 53a, 53b) caused by giving the outer part of the third ring (50c) a rhombic cross-section with an angle of 72 degrees and by displacing another outer leg part of the third ring toward the fifth ring (50e) when it goes within the complete leg.
13. A transformer core according to claim 10, **characterised by** multi-edged cross-sections of their legs and profile rings comprising a first cluster of rings with rhombic cross-sections with different angles but in their leg parts turned the same angle and attached to the multi-edged cross-section, and inside a second cluster of rings with rhombic cross-section with different angles, but in their leg parts turned the same angle and attached to the first cluster and so on until innermost there arises space for rings, which in one of their leg parts is given a cross-section and turning differently from those in the other leg part.
14. A transformer core according to claim 1, **characterised in that** all rings have a rhombic cross-section with two angles of 60 degrees and two angles of 120 degrees.
15. A transformer core according to claim 1, **characterised by** an additional core (70) of strips between windings brought together at the top and the bottom of the core.
16. A transformer core according to claim 1, **characterised by** an additional core in the centre line of at least one strip pole, and if many, arranged three and three in a package (figs. 8 and 9), which poles are bent to each yoke.
17. A transformer core according to claim 1, **characterised in that** segments between the cross-sections of the legs and a circumscribed circle are partly filled by thin rings and/or slightly broader strips.

Patentansprüche

1. Transformatorkern, der drei Schenkel und die Schenkel verbindende Jochteile umfasst, wobei der Querschnitt der Schenkel der gleiche ist und in Form eines regelmäßigen Vielecks mit mehr als vier Kanten vorliegt, **dadurch gekennzeichnet, dass** der Kern allein aus aus Streifen mit konstanter Breite gewickelten Ringen besteht, wobei verschiedene Ringe verschiedene Breiten aufweisen können und jeder der Ringe einen Teil von zwei der Schenkel bildet.
2. Transformatorkern nach Anspruch 1, **dadurch gekennzeichnet, dass** die Schenkel einen sechseckigen Querschnitt aufweisen.
3. Transformatorkern nach Anspruch 2, **dadurch gekennzeichnet, dass** er neun Ringe umfasst.
4. Transformatorkern nach Anspruch 3, **dadurch gekennzeichnet, dass** er drei Ringe mit einer ersten Breite und einer ersten Höhe und sechs Ringe mit einer zweiten Breite, die der Hälfte der ersten Breite entspricht, und einer zweiten Höhe, die der Hälfte

der ersten Höhe entspricht, umfasst.

5. Transformator kern nach Anspruch 4, gekennzeichnet durch:

einen ersten (32), einen zweiten (33) und einen dritten (34) ringförmigen Teil, wobei jeder ringförmige Teil:

einen ersten Ring (32a, 33a, 34a), der aus Streifen mit einer ersten Breite auf eine erste Höhe gewickelt ist, wobei der Querschnitt der Ringe rautenförmig mit zwei Winkel von 60 Grad ist,

einen zweiten Ring (32b, 33b, 34b), der aus einem Streifen mit einer zweiten Breite, die im Wesentlichen der Hälfte der ersten Breite entspricht, auf eine zweite Höhe gewickelt ist, die im Wesentlichen der Hälfte der ersten Höhe entspricht, wobei der zweite Ring einen rautenförmigen Querschnitt aufweist und auf dem ersten Ring (32a, 33a, 34a) positioniert ist,

einen dritten Ring (32c, 33c, 34c) der aus einem Streifen mit der zweiten Breite zu der zweiten Höhe gewickelt ist, wobei der zweite Ring einen rautenförmigen Querschnitt aufweist und in einer Position auf dem ersten Ring (32a, 33a, 34a) neben dem zweiten Ring und in einer anderen Position auf dem zweiten Ring positioniert ist,

umfasst,

wobei der erste, der zweite und der dritte ringförmige Teil zusammengefügt sind, wodurch ein Dreiphasentransformator kern mit drei Schenkeln mit sechseckigen Querschnitten gebildet wird.

6. Transformator kern nach Anspruch 2, dadurch gekennzeichnet, dass er sieben Ringe umfasst.

7. Transformator kern nach Anspruch 6, gekennzeichnet durch:

einen ersten (22a), einen zweiten (23a) und einen dritten (24a) Ring, die aus Streifen mit einer ersten Breite auf eine erste Höhe gewickelt sind, wobei die Querschnitte der Ringe rautenförmig mit zwei Winkeln von 60 Grad sind, wobei der erste, der zweite und der dritte Ring Jochteile bilden, die zusammen ein Dreieck bilden, einen vierten Ring (24b), der aus einem Streifen mit der ersten Breite auf eine zweite Höhe gewickelt ist, die im Wesentlichen der Hälfte der ersten Höhe entspricht, wobei der vierte Ring einen rautenförmigen Querschnitt aufweist und auf dem dritten Ring (24a) positioniert ist, einen fünften Ring (22b), der aus einem Streifen

mit einer zweiten Breite, die im Wesentlichen der Hälfte der ersten Breite entspricht, auf die erste Höhe gewickelt ist, wobei der fünfte Ring einen rautenförmigen Querschnitt aufweist und auf dem ersten Ring (22a) positioniert ist, einen sechsten Ring (23b), der aus einem Streifen mit der zweiten Breite auf die zweite Höhe gewickelt ist, wobei der sechste Ring einen rautenförmigen Querschnitt aufweist und auf dem zweiten Ring (23a) positioniert ist, und einen siebten Ring (23c), der aus einem Streifen mit der zweiten Breite auf die zweite Höhe gewickelt ist, wobei der siebte Ring einen rautenförmigen Querschnitt aufweist und auf dem zweiten Ring (23a) und auf dem sechsten Ring (23b) positioniert ist,

wodurch ein Dreiphasentransformator kern mit drei Schenkeln mit sechseckigen Querschnitten gebildet wird.

8. Transformator kern nach Anspruch 1, dadurch gekennzeichnet, dass die Schenkel einen achteckigen Querschnitt aufweisen.

9. Transformator kern nach Anspruch 8, gekennzeichnet durch einen ersten, einen zweiten und einen dritten Profiling, die jeweils drei Ringe (42a, 42b, 42c) mit zwei Schenkelteilen und zwei Jochteilen aufweisen, wobei

ein erster Ring (42a) einen rautenförmigen Querschnitt in seinen Schenkelteilen mit einem Winkel von 45 Grad aufweist, wobei die Jochteile in einem Winkel von 15 Grad in einer solchen Richtung gebogen sind, dass die Außenseitenflächen seiner Schenkelteile zueinander bewegt werden, ein zweiter Ring (42b) quadratische Querschnitte in seinen Schenkelteilen aufweist und auf dem ersten Ring positioniert ist, und ein dritter Ring (42c) rautenförmige Querschnitte in seinen Schenkelteilen aufweist, wobei ein erster Schenkelteil mit 45 Grad in erster Linie auf dem ersten Ring (42a) liegt und ein zweiter Schenkelteil mit 135 Grad auf dem zweiten Ring (42b) liegt, wobei der erste, der zweite und der dritte Profiling zusammengefügt sind, wodurch ein Dreiphasentransformator kern mit drei Schenkeln mit achteckigen Querschnitten gebildet wird.

10. Transformator kern nach Anspruch 1, dadurch gekennzeichnet, dass die Schenkel einen Querschnitt mit zehn Kanten aufweisen.

11. Transformator kern nach Anspruch 10, gekennzeichnet durch einen ersten, einen zweiten und einen dritten Profiling, die jeweils fünf Ringe (50a-e) mit zwei Schenkelteilen und zwei Jochteilen aufwei-

sen,

wobei

ein erster Ring (50a) rautenförmige Querschnitte in seinen Schenkelteilen mit einem Winkel von 36 Grad aufweist,

ein zweiter Ring (50b) rautenförmige Querschnitte in seinen Schenkelteilen mit einem Winkel von 72 Grad aufweist,

ein dritter Ring (50c) rautenförmige Querschnitte in seinen Schenkelteilen mit einem Winkel von 108 Grad aufweist,

ein vierter Ring (50d) rautenförmige Querschnitte in seinen Schenkelteilen mit einem Winkel von 36 Grad aufweist und in erster Linie auf dem ersten Ring (50a) liegt und dessen Jochteile in einem Winkel von 24 Grad nach außen ausgerichtet sind, und

ein fünfter Ring (50e) rautenförmige Querschnitte in seinen Schenkelteilen mit einem Winkel von 144 Grad, wenn er auf dem dritten Ring (50c) liegt, aber einen rautenförmigen Querschnitt mit einem Winkel

von 72 Grad, wenn er außerhalb des vierten Rings (50d) liegt, und einen Kanal (51), der sich zum Kühlen des Schenkels außerhalb des fünften Rings (50e) eignet, aufweist,

wobei der erste, der zweite und der dritte Profilring zusammengefügt sind, wodurch ein Dreiphasentransformatorkern mit drei Schenkeln mit zehneckigen Querschnitten gebildet wird.

12. Transformatorkern nach Anspruch 11, **gekennzeichnet durch** Kühlkanäle (52a, 52b, 53a, 53b), die **dadurch** gebildet werden, dass dem Außenteil des dritten Rings (50c) ein rautenförmiger Querschnitt mit einem Winkel von 72 Grad verliehen wird und ein anderer Außenteil des dritten Rings zu dem fünften Ring (50e) verschoben wird, wenn er in den vollständigen Schenkel gelangt.

13. Transformatorkern nach Anspruch 10, **gekennzeichnet durch** mehrkantige Querschnitte seiner Schenkel und Profilringe, mit einer ersten Gruppe von Ringen mit rautenförmigen Querschnitten mit verschiedenen Winkeln, wobei ihre Schenkelteile aber in dem gleichen Winkel ausgerichtet und an dem mehrkantigen Querschnitt befestigt sind, und innen einer zweiten Gruppe von Ringen mit rautenförmigem Querschnitt mit verschiedenen Winkeln, wobei ihre Schenkelteile aber in dem gleichen Winkel ausgerichtet und an der ersten Gruppe befestigt sind, usw., bis am weitesten innen liegend ein Raum für Ringe gebildet wird, denen in einem ihrer Schenkelteile ein anderer Querschnitt verliehen wird und die anders ausgerichtet sind als der andere Schenkelteil.

14. Transformatorkern nach Anspruch 1, **dadurch gekennzeichnet, dass** alle Ringe einen rautenförmigen Querschnitt mit zwei Winkeln von 60 Grad und

zwei Winkeln von 120 Grad aufweisen.

15. Transformatorkern nach Anspruch 1, **gekennzeichnet durch** einen zusätzlichen Kern (70) mit Streifen zwischen Wicklungen, die oben und unten am Kern zusammengebracht werden.

16. Transformatorkern nach Anspruch 1, **gekennzeichnet durch** einen zusätzlichen Kern in der Mittellinie mindestens eines Streifenpols, die, wenn viele vorgesehen sind, drei und drei zu einem Paket (Figuren 8 und 9) angeordnet sind, wobei die Pole zu jedem Joch gebogen sind.

17. Transformatorkern nach Anspruch 1, **dadurch gekennzeichnet, dass** Segmente zwischen den Querschnitten der Schenkel und einem umschriebenen Kreis teilweise durch dünne Ringe und/oder etwas breitere Streifen gefüllt sind.

Revendications

1. Noyau de transformateur, comprenant trois pattes et des parties de joug connectant lesdites pattes, la section transversale desdites pattes étant la même et en forme d'un polygone régulier ayant plus de quatre côtés, **caractérisé en ce que** le noyau est seulement constitué d'anneaux enroulés à partir de bandes de largeur constante, différents anneaux pouvant avoir des largeurs différentes et chacun desdits anneaux constituant une partie de deux desdites pattes.

2. Noyau de transformateur selon la revendication 1, **caractérisé en ce que** lesdites pattes ont une section transversale hexagonale.

3. Noyau de transformateur selon la revendication 2, **caractérisé en ce qu'il** comprend neuf anneaux.

4. Noyau de transformateur selon la revendication 3, **caractérisé en ce qu'il** comprend trois anneaux d'une première largeur et d'une première hauteur et six anneaux d'une deuxième largeur correspondant à la moitié de la première largeur et d'une deuxième hauteur correspondant à la moitié de la première hauteur.

5. Noyau de transformateur selon la revendication 4, **caractérisé par** une première (32), une deuxième (33) et une troisième (34) partie en forme d'anneau, chaque partie en forme d'anneau comprenant un premier anneau (32a, 33a, 34a) enroulé à partir de bandes d'une première largeur jusqu'à une première hauteur, les sections transversales desdits anneaux étant rhombiques avec deux angles de 60 de-

- grés,
un deuxième anneau (32b, 33b, 34b) enroulé à partir d'une bande d'une deuxième largeur correspondant essentiellement à la moitié de la première largeur, jusqu'à une deuxième hauteur correspondant essentiellement à la moitié de la première hauteur, ledit deuxième anneau ayant une section transversale rhombique et étant positionné sur ledit premier anneau (32a, 33a, 34a),
un troisième anneau (32c, 33c, 34c) enroulé à partir d'une bande de la deuxième largeur jusqu'à la deuxième hauteur, ledit troisième anneau ayant une section transversale rhombique et étant positionné dans une position sur ledit premier anneau (32a, 33a, 34a) adjacente audit deuxième anneau et dans une autre position sur ledit deuxième anneau, lesdites première, deuxième et troisième parties en forme d'anneau étant assemblées de telle sorte qu'un noyau de transformateur triphasé avec trois pattes de sections transversales hexagonales soit formé.
6. Noyau de transformateur selon la revendication 2, **caractérisé en ce qu'il** comprend sept anneaux.
7. Noyau de transformateur selon la revendication 6, **caractérisé par**
un premier (22a), un deuxième (23a) et un troisième (24a) anneau enroulé à partir de bandes d'une première largeur jusqu'à une première hauteur, les sections transversales desdits anneaux étant rhombiques avec deux angles de 60 degrés, lesdits premier, deuxième et troisième anneaux formant des parties de joug constituant ensemble un triangle, un quatrième anneau (24b) enroulé à partir d'une bande de ladite première largeur jusqu'à une deuxième hauteur correspondant essentiellement à la moitié de la première hauteur, ledit quatrième anneau ayant une section transversale rhomboïde et étant positionné sur ledit troisième anneau (24a), un cinquième anneau (22b) enroulé à partir d'une bande d'une deuxième largeur correspondant essentiellement à la moitié de la première largeur, jusqu'à ladite première hauteur, ledit cinquième anneau ayant une section transversale rhomboïde et étant positionné sur ledit premier anneau (22a), un sixième anneau (23b) enroulé à partir d'une bande de la deuxième largeur jusqu'à ladite deuxième hauteur, ledit sixième anneau ayant une section transversale rhombique et étant positionné sur ledit deuxième anneau (23a), et
un septième anneau (23c) enroulé à partir d'une bande de la deuxième largeur jusqu'à ladite deuxième hauteur, ledit septième anneau ayant une section transversale rhombique et étant positionné sur ledit deuxième anneau (23a) et sur ledit sixième anneau (23b),
un noyau de transformateur triphasé à trois pattes avec des sections transversales hexagonales étant ainsi formé.
8. Noyau de transformateur selon la revendication 1, **caractérisé en ce que** lesdites pattes ont une section transversale octogonale.
9. Noyau de transformateur selon la revendication 8, **caractérisé par** un premier, un deuxième et un troisième anneau profilé, chacun comprenant trois anneaux (42a, 42b, 42c) avec deux parties de pattes et deux parties de joug, un premier anneau (42a) ayant une section transversale rhombique dans ses parties de pattes avec un angle de 45 degrés et les parties de joug étant recourbées de 15 degrés dans une direction telle que les faces latérales externes de ses parties de pattes soient déplacées l'une vers l'autre, un deuxième anneau (42b) ayant des sections transversales quadratiques dans ses parties de pattes et étant positionné sur ledit premier anneau, et un troisième anneau (42c) ayant des sections transversales rhombiques dans ses parties de pattes, une première partie de patte à 45 degrés reposant principalement sur ledit premier anneau (42a) et une deuxième partie de patte à 135 degrés reposant principalement sur ledit deuxième anneau (42b), lesdits premier, deuxième et troisième anneaux profilés étant assemblés pour ainsi former un noyau de transformateur triphasé avec trois pattes ayant des sections transversales octogonales.
10. Noyau de transformateur selon la revendication 1, **caractérisé en ce que** lesdites pattes ont une section transversale avec dix côtés.
11. Noyau de transformateur selon la revendication 10, **caractérisé par** un premier, un deuxième et un troisième anneau profilé, chacun comprenant cinq anneaux (50a-e), avec deux parties de pattes et deux parties de joug, dans lequel :
un premier anneau (50a) ayant des sections transversales rhombiques dans ses parties de pattes à un angle de 36 degrés,
un deuxième anneau (50b) ayant des sections transversales rhombiques dans ses parties de pattes à un angle de 72 degrés,
un troisième anneau (50c) ayant des sections transversales rhombiques dans ses parties de pattes à un angle de 108 degrés,
un quatrième anneau (50d) ayant des sections transversales rhombiques dans ses parties de pattes à un angle de 36 degrés et reposant principalement sur le premier anneau (50a) et ayant ses parties de joug tournées vers l'extérieur de 24 degrés, et
un cinquième anneau (50e) ayant des sections

transversales rhombiques dans ses parties de pattes à un angle de 144 degrés lorsqu'il repose sur le troisième anneau (50c) mais une section transversale rhombique à un angle de 72 degrés lorsqu'il repose en dehors du quatrième anneau (50d), et un canal (51) adapté pour refroidir la patte en dehors du cinquième anneau (50e), lesdits premier, deuxième et troisième anneaux profilés étant assemblés de manière à former un noyau de transformateur triphasé avec trois pattes ayant des sections transversales à 10 côtés.

tions transversales des pattes et un cercle circonscrit sont partiellement remplis par de minces anneaux et/ou des bandes légèrement plus larges.

12. Noyau de transformateur selon la revendication 11, **caractérisé par** des canaux de refroidissement (52a, 52b, 53a, 53b) réalisés en conférant à la partie externe du troisième anneau (50c) une section transversale rhombique à un angle de 72 degrés et en déplaçant une autre partie de patte externe du troisième anneau vers le cinquième anneau (50e) lorsqu'il va à l'intérieur de toute la patte. 15 20
13. Noyau de transformateur selon la revendication 10, **caractérisé par** des sections transversales polygonales de ses pattes et des anneaux profilés comprenant un premier groupe d'anneaux de sections transversales rhombiques à des angles différents, mais, dans leurs parties de pattes, tournés suivant le même angle et attachés à la section transversale polygonale, et à l'intérieur, un deuxième groupe d'anneaux de section transversale rhombique à des angles différents, mais, dans leurs parties de pattes, tournés suivant le même angle et attachés au premier groupe, et ainsi de suite jusqu'au centre, où il apparaît un espace pour des anneaux, qui, dans l'une de leurs parties de pattes, ont une section transversale et une orientation différentes de celles dans l'autre partie de patte. 25 30 35
14. Noyau de transformateur selon la revendication 1, **caractérisé en ce que** tous les anneaux ont une section transversale rhombique avec deux angles de 60 degrés et deux angles de 120 degrés. 40
15. Noyau de transformateur selon la revendication 1, **caractérisé par** un noyau supplémentaire (70) de bandes entre des enroulements réunis en haut et en bas du noyau. 45
16. Noyau de transformateur selon la revendication 1, **caractérisé par** un noyau supplémentaire dans l'axe central d'au moins un pôle de bande, et, s'il y en a plusieurs, agencés trois par trois dans un paquet (figures 8 et 9), lesquels pôles sont tournés vers chaque joug. 50 55
17. Noyau de transformateur selon la revendication 1, **caractérisé en ce que** des segments entre les sec-

Fig. 1

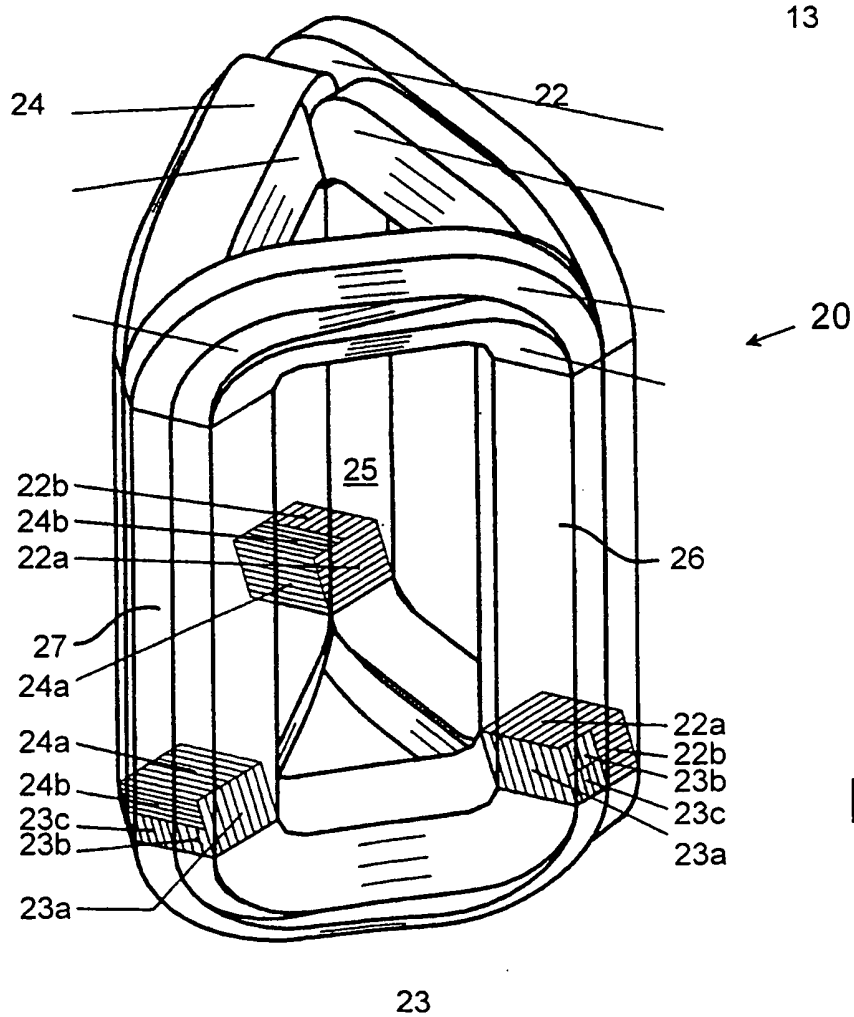
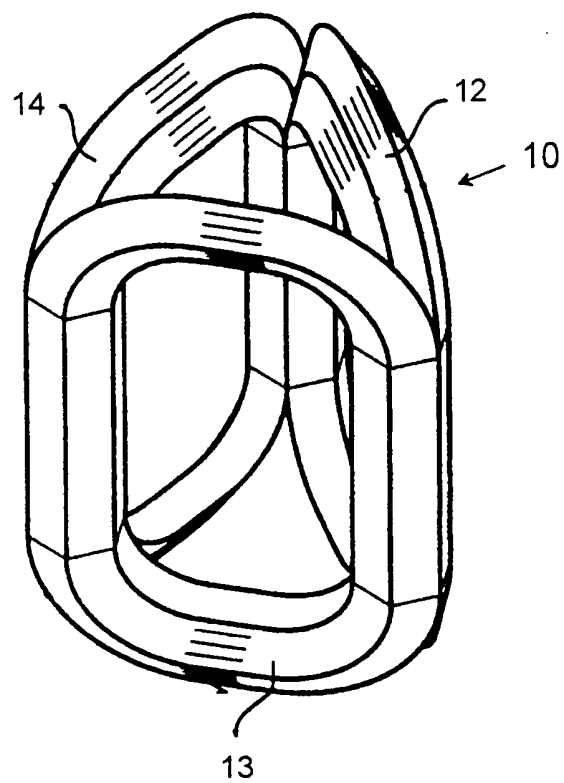


Fig. 2

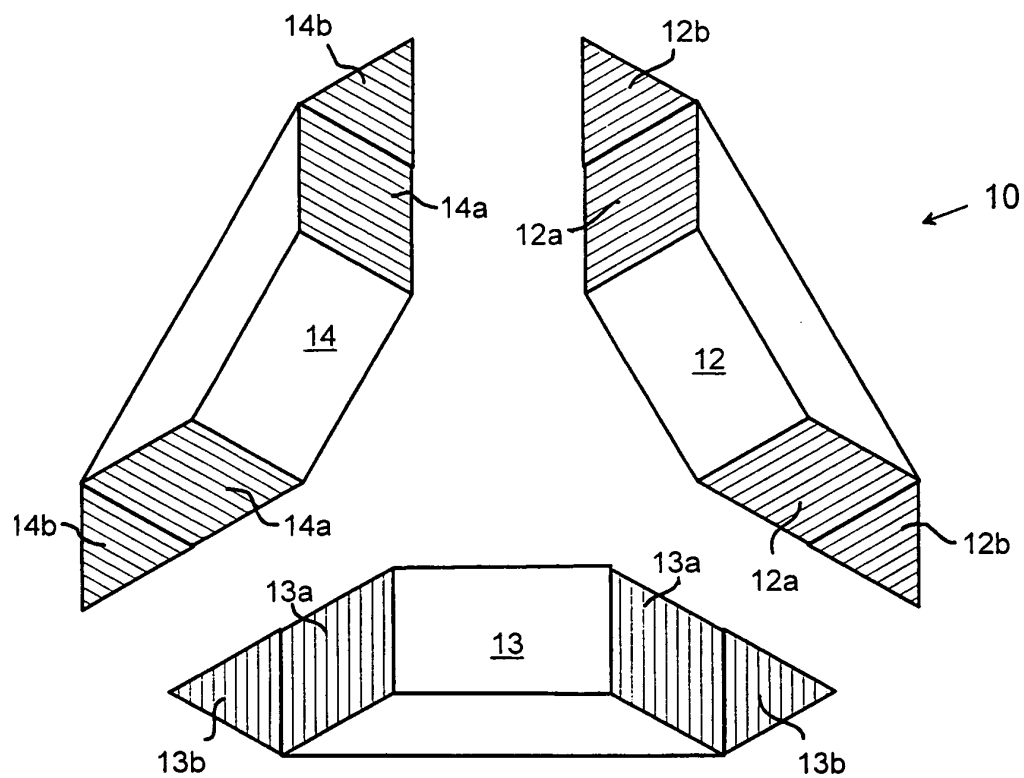


Fig. 1a

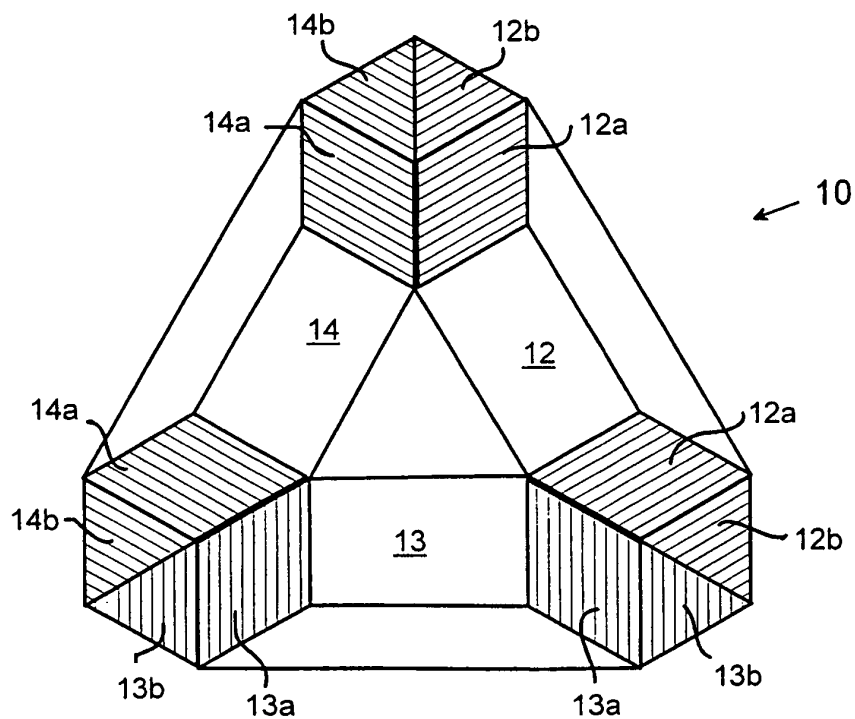
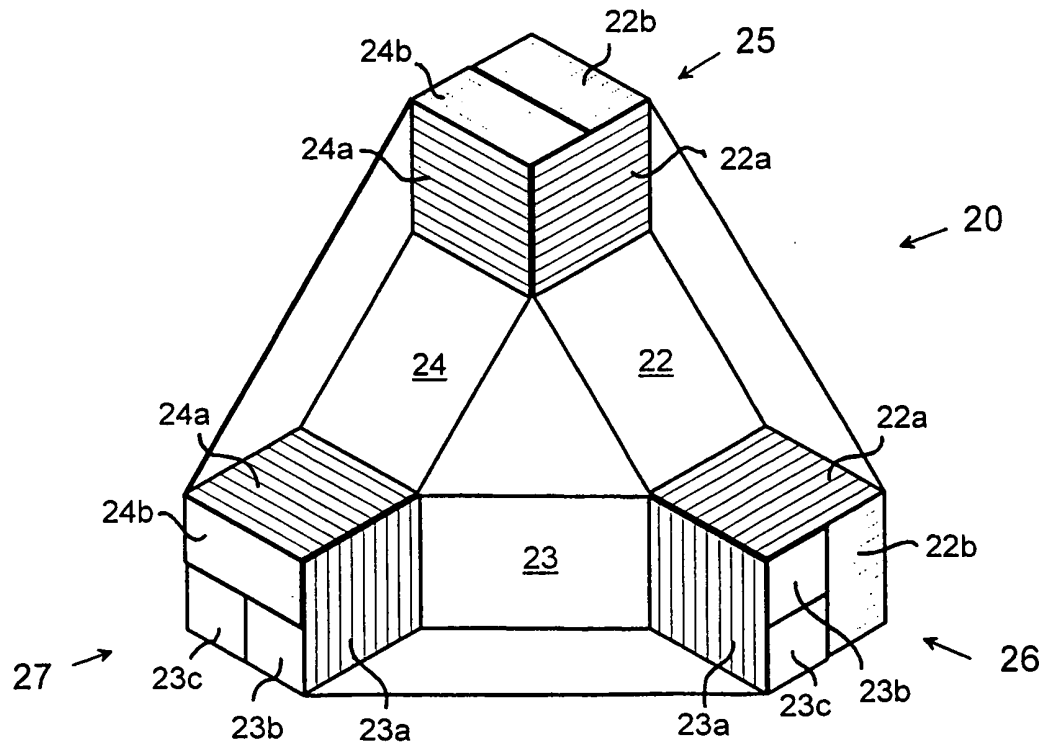
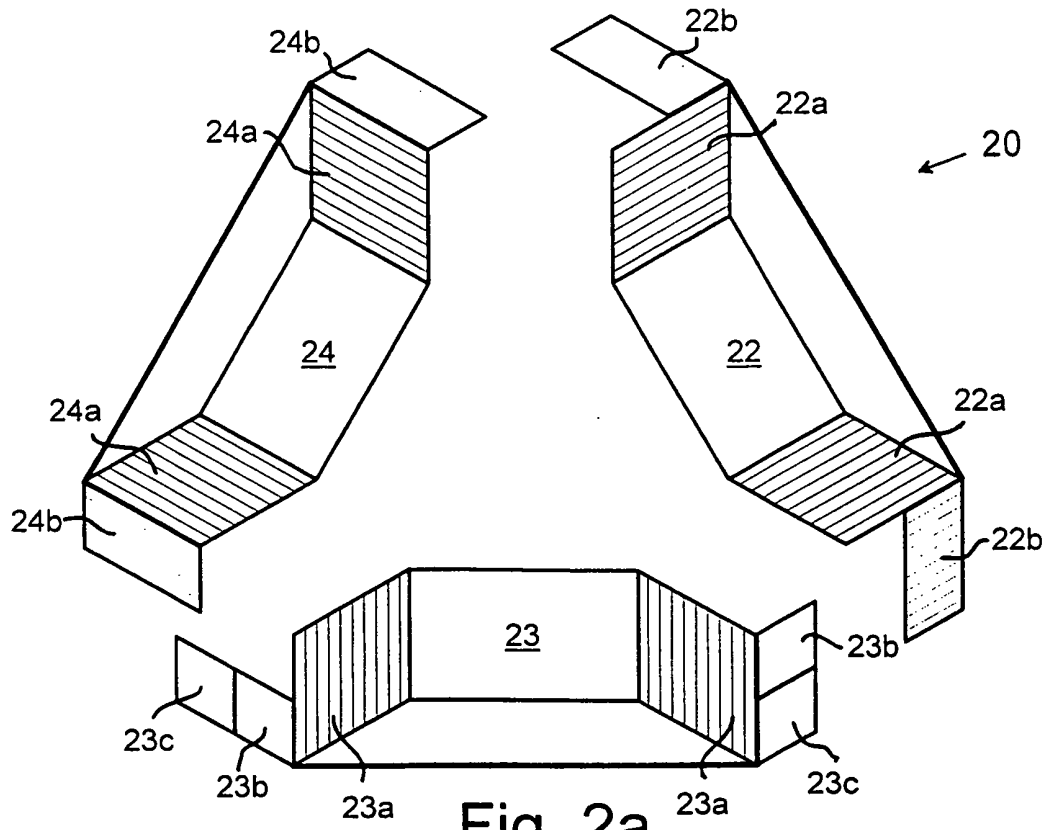


Fig. 1b



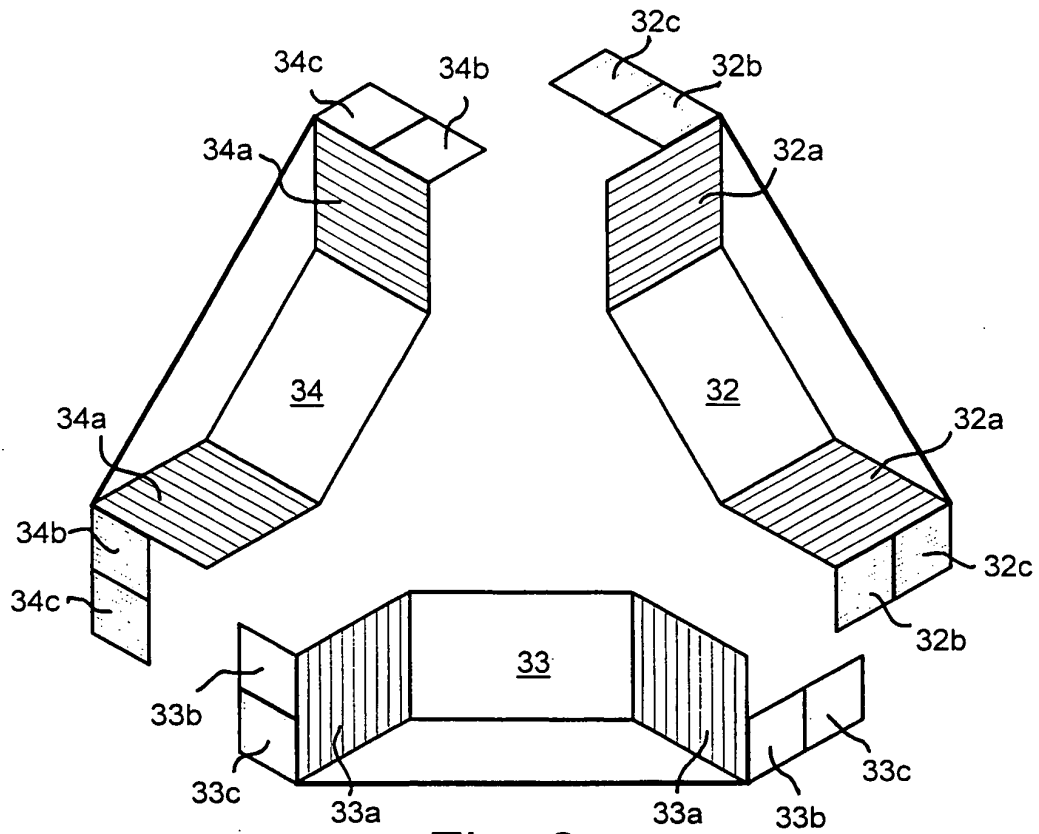


Fig. 3a

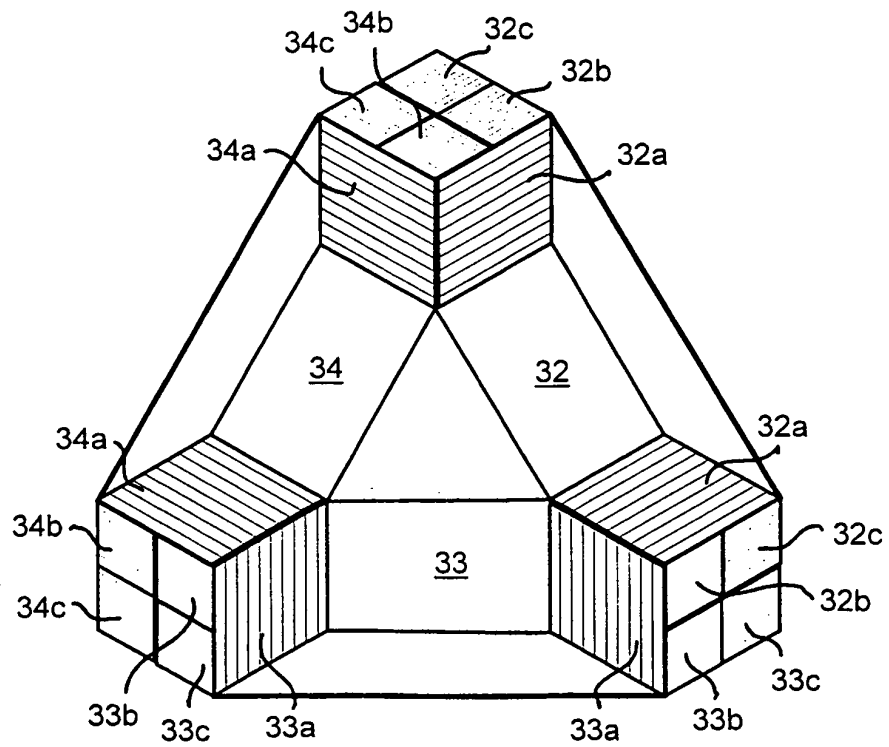


Fig. 3b

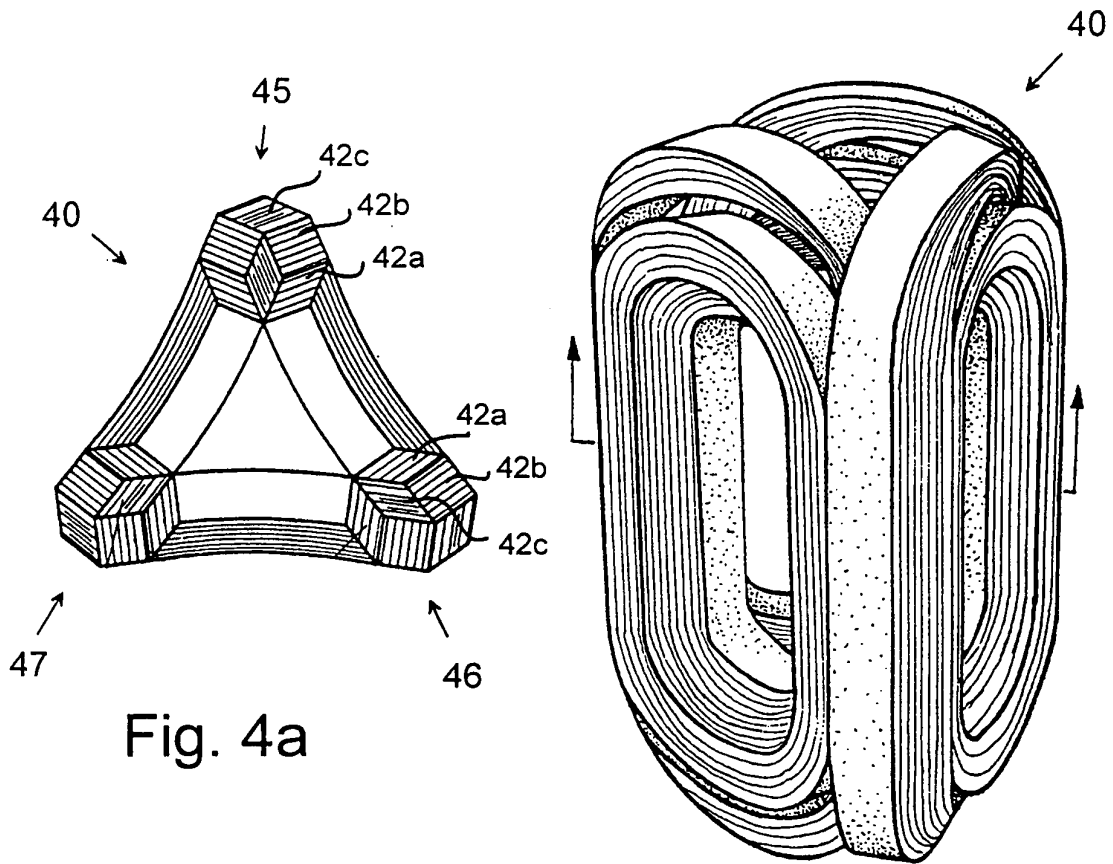


Fig. 4a

Fig. 4

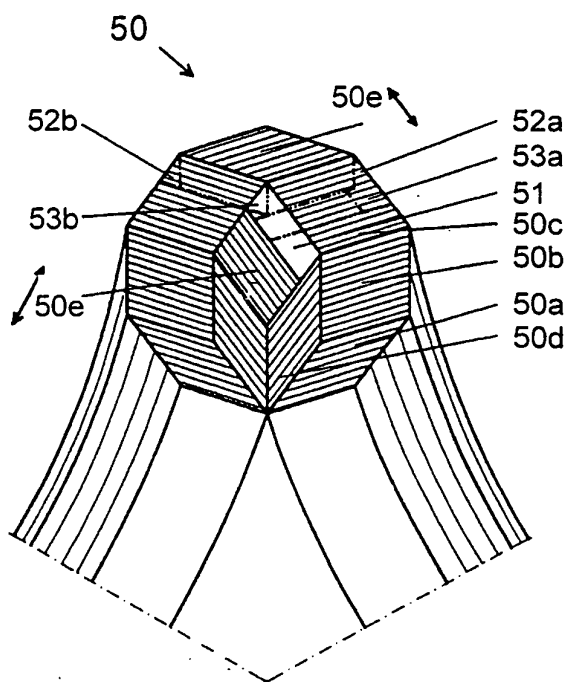


Fig. 5

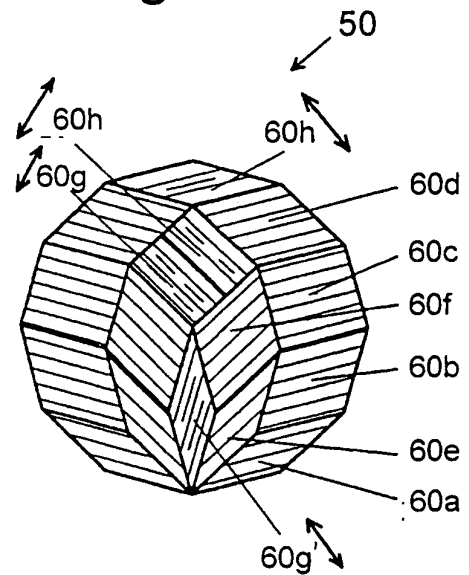


Fig. 6

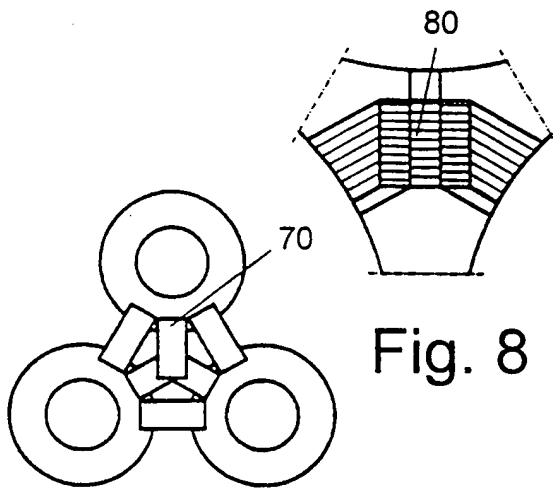


Fig. 8

Fig. 7

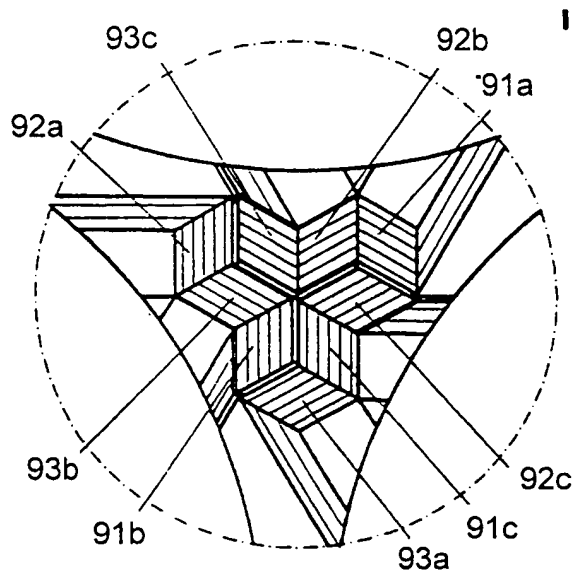


Fig. 9

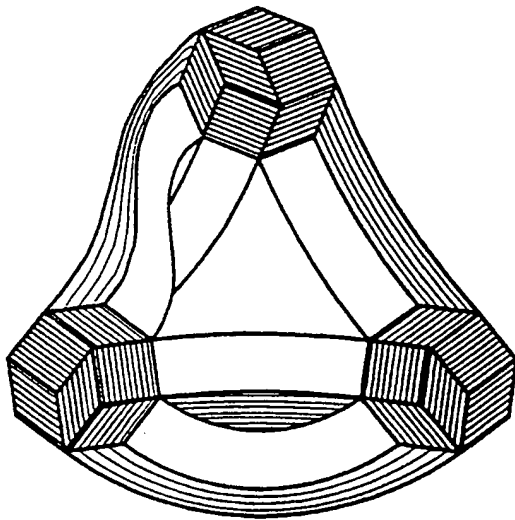


Fig. 10

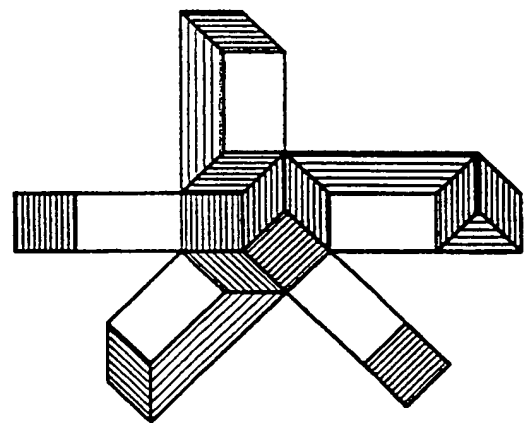


Fig. 12

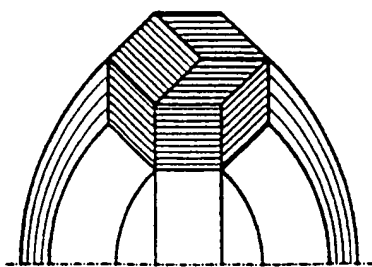


Fig. 13

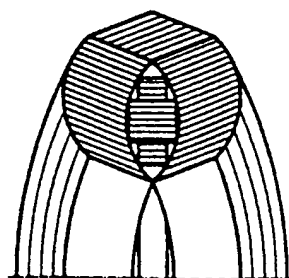


Fig. 14

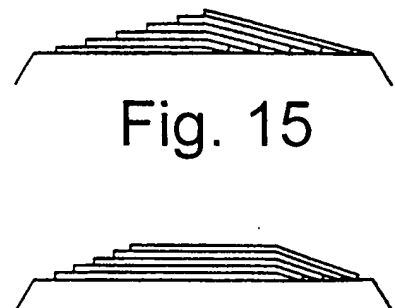


Fig. 15

Fig. 16

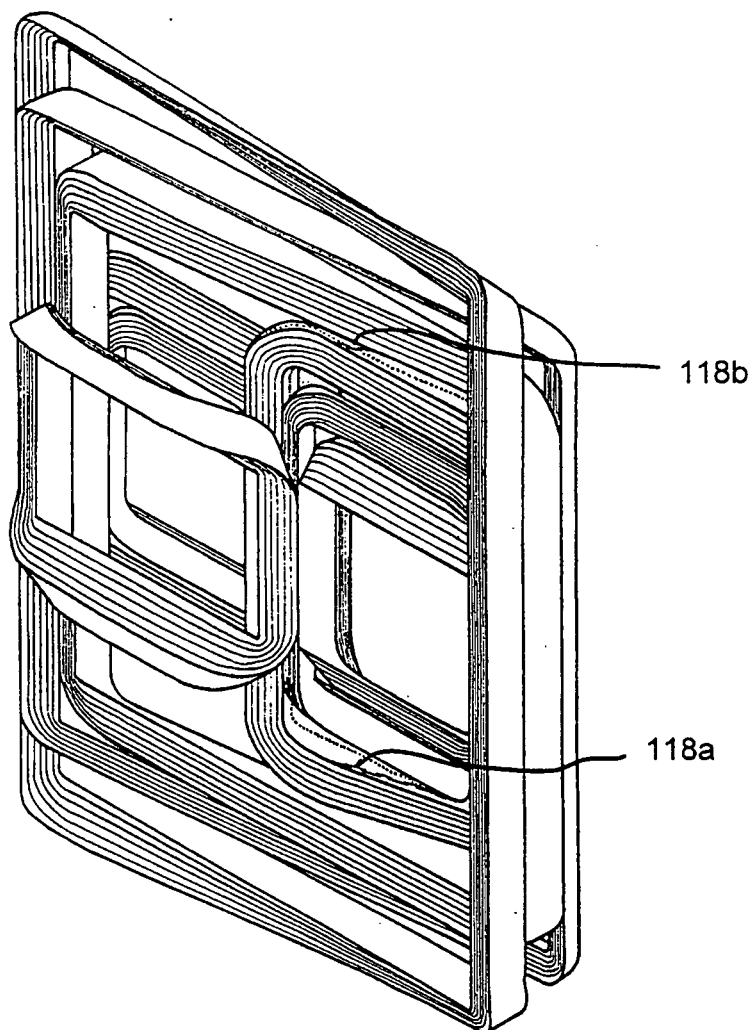


Fig. 11

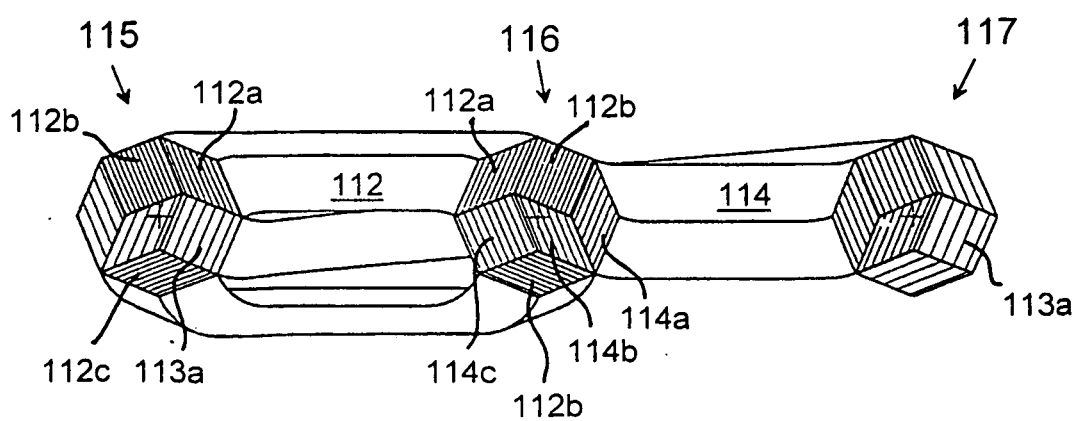


Fig. 11a

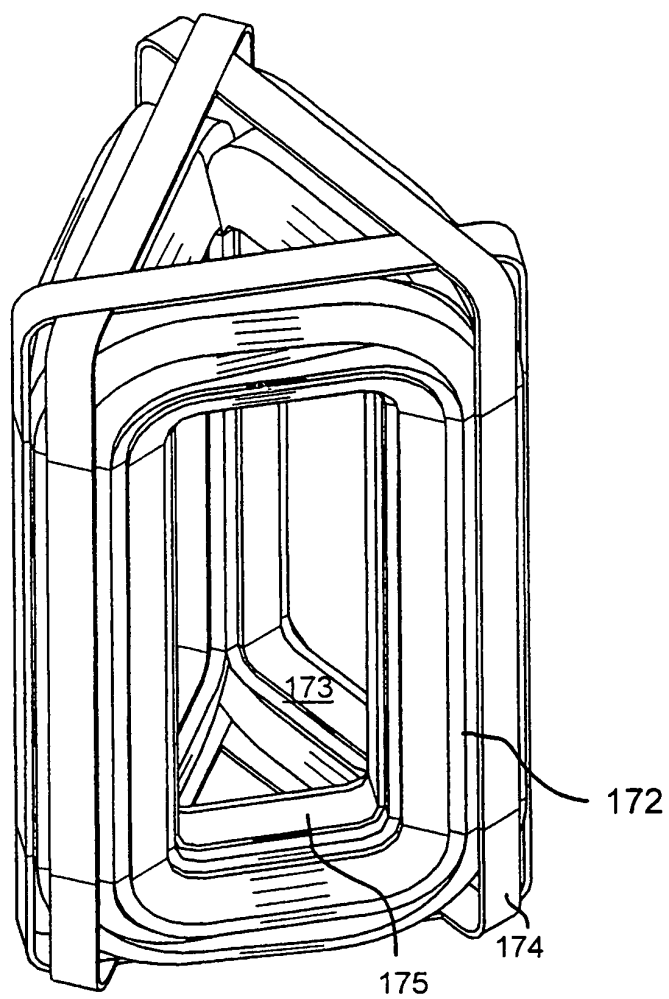


Fig. 17

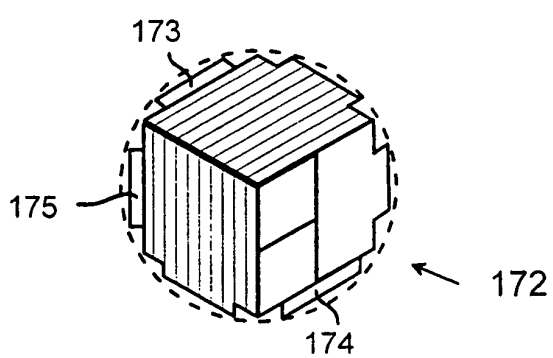


Fig. 17a

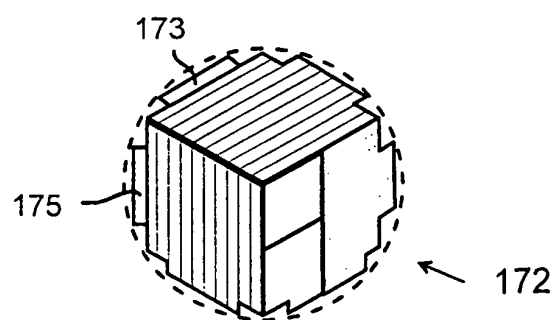


Fig. 17b

REFERENCES CITED IN THE DESCRIPTION

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