

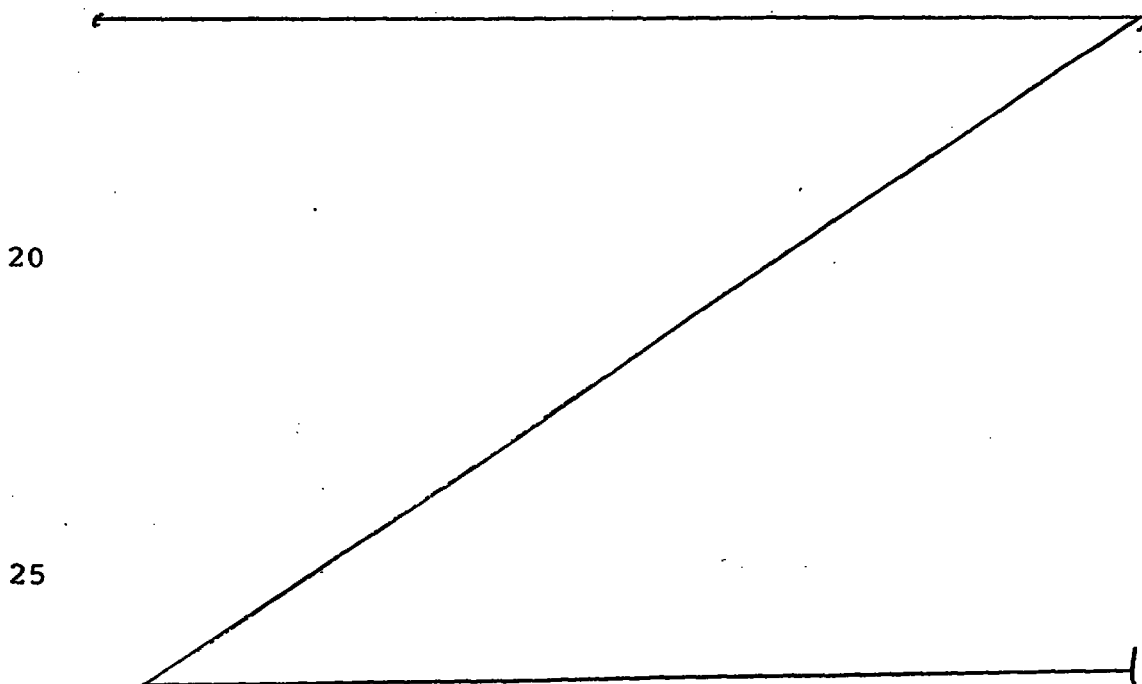
IMPROVEMENTS IN LAMINATIONS

This invention relates to improved laminations for electromagnetic devices for making up magnetic cores thereof, to packs of said laminations and to methods of assembling said packs to form magnetic cores.

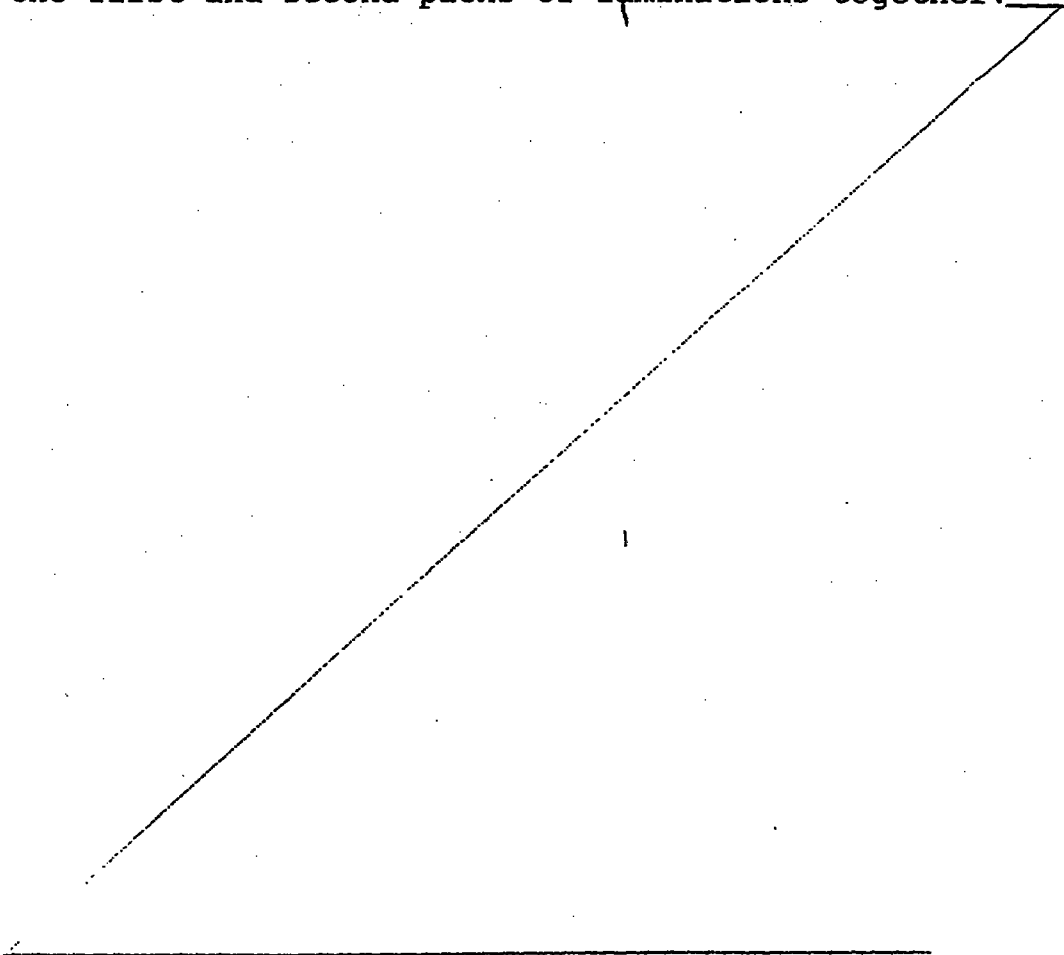
- 5 Electromagnetic devices e.g. transformers and electric motors commonly have cores made up of individual laminations which may take the form of a butted stack, an interleaved stack or a so-called "Unilam" (registered Trade Mark) stack (see Patent No's
- 10 GB-A-1466878, 1466879 and 1466880). A variety of ways have been used to hold the laminations together to make a core for the device. They have been bolted together. They have been welded together. They have been adhered together. They have been enclosed within
- 15 a retaining frame. But all these methods are costly because they involve additional components and/or add to the time and number of operations needed to assemble the core.

- It has been proposed in Patent Specification No.
- 20 US-A-4594295 to provide cut sheet metal laminations that may be force fitted together to avoid transformer noise at high load/temperature working conditions. Thus one of the laminations has small narrow projections that are a force or interference fit into

corresponding recesses of a complementary lamination. But it is inherent in the force fit method of assembly that the complementary parts resist assembly, and any resulting incompleteness in the mechanical contact
5 between the assembled parts increases the magnetic reluctance of the device, and corresponding loss of efficiency. Furthermore the said US Patent does not rely on force fitting as sole means for holding the laminations together but also fastens the laminations
10 by welding as is conventional in the art. Force fitting is also described in Specification No's DE-A-2744711, 3008598 and 3008599. Our Patent Specification No. EP-A-0028494 describes and claims F-lamination parts for use in the magnetic cores of
15 transformers having projections and recesses that are subject to an interference fit.



In one aspect the invention provides a lamination assembly for an electromagnetic device comprising first and second packs of complementary laminations that fit together and have interfitting formations, the formations of one of the packs of laminations being projections that are permanently deformed inwardly towards the complementary formations of the other pack of laminations so as to permanently fasten the first and second packs of laminations together.



In a further aspect, the invention provides a method of assembling packs of laminations of an electromagnetic device, which comprises: providing first and second packs of complementary laminations that fit together and have interfitting formations; holding the first and second packs of laminations positively together in mechanical contact; and deforming said formations on one or both of the packs of laminations to engage the formations of the other pack of laminations to clamp the first and second packs of laminations together.

In a third aspect the invention provides first and second packs of laminations when provided as a set for assembly into a lamination assembly for a magnetic device as aforesaid, said first and second packs of complementary laminations having the ability to fit together and having interfitting formations, the formations of one of the packs of laminations being projections that are permanently deformable inwardly towards the complementary formations of the other pack of laminations so as, after assembly, to permanently fasten the first and second packs of laminations together.

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The invention may enable the laminations of electromagnetic devices to be assembled together simply and inexpensively in few operations and with minimal loss in performance.

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The facility to assemble the laminations freely together enables them to be offered together and held in good mechanical contact by an external clamping

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force until the deformable portions are mechanically deformed to hold the packs together.

The interfitting formations of the first and second packs of laminations may simply give rise to a frictional clamping force when deformable ones of them are deformed onto non-deforming others of them but preferably they are profiled so that deformation of said formations mechanically fastens the first and second packs together. In the latter case, the interfitting formations of the first and second packs of laminations advantageously have a dovetail or other profile such that deformation of said formations positively urges the first and second packs of laminations together. The dovetail is advantageously formed on the non-deforming seat formation but it may also be formed on a deformable ear formation.

Preferably the free interfitting is provided by a clearance fit but it may also be provided by a transition fit, line contact between the male and female parts offering little resistance to assembly. Any force needed to assemble the stacks of laminations together should be relatively small compared to the available clamping force.

Again, if the male and female parts are a tight transition fit, the properties of the product may be acceptable if the resistance reduces during the last part of the travel of the first and second packs of
5 laminations towards the fully abutted position.

The above method of assembly can be used for loose laminations and stacked laminations. Thus a rigid pack of E-laminations may be assembled to a pack of I-laminations which is flexible e.g. because the
10 undivided laminations are held together by a single peg. With this flexibility the I-laminations easily accomodate any irregularities in the E-laminations and good mechanical and magnetic contact is obtained. However, the use of two or more pegs for both
15 E-laminations and I-laminations is within the invention.

Optionally, each lamination of the or each torsionally flexible pack comprises, on a common axis perpendicular to the lamination, a single depression
20 on one side thereof and a single projection on the other side thereof, each lamination being coupled to an adjacent lamination only by the single projection projecting into the single depression of the adjacent lamination.

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Various forms of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1a is a front view of components of an electrical transformer prior to assembly, and Figures 1b, 1c and 1d are respectively a central transverse section of a pack of I-laminations, a transverse section of a core and an end view of a pack of E-laminations all being components that appear in Figure 1;

Figure 2a is a front view of a transformer assembled from the components shown in Figure 1, Figure 2b is an enlarged detail of one side of the transformer core at an interface between the I- and E-laminations prior to attachment of them together and Figure 2c and 2d are end views of the transformer showing alternative core structures;

Figure 3 is a front view of the transformer during assembly.

5 Figures 4a, 4b and 4c are enlarged details of one side of the transformer core at an interface between I- and E-laminations after attachment together and showing alternative notch profiles;

10 Figures 5a, 5b and 5c are enlarged details of one side of the transformer core at an interface between an I- and an E-lamination showing the use of different notch angles and crimp blade profiles;

15 Figures 6a to 6e are front views of typical laminate assemblies for a variety of transformers and chokes assembled according to the invention;

20 Figure 7 is a diagrammatic front view of a core of a shaded pole motor assembled according to the invention;

25 Figures 8a and 8b are front and side views of an interleaved stack of I- and E-laminations according to the invention and Figure 8c is a view of the I- and E-laminations from which the interleaved stack is formed;

Figures 9 and 10 are front views of transformer laminations showing an alternative form of attachment;

5 Figures 11, 11a and 12, 12a are detail views showing alternative notch and projection profiles for use in the laminations of Figures 9 and 10; and

Figures 13 and 13a are detail views showing a yet further notch and projection profile.

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In Figure 1a and Figures 1b, 1c and 1d a transformer 10 has windings 11 and a core assembled from an E-lamination pack 12 and an I-lamination pack 14. The laminations of the E-lamination pack 10 are held
15 together by a pair of stamped-in spigot and socket fasteners. The upper extremities of the E-laminations of the pack 12 are formed on the outer edges thereof with dovetail formations 16 and the I-laminations of the pack 14 are formed with deformable projections or
20 ears 18. The dovetail formations 16 and the ears 18 are desirably formed on the respective laminations during stamping or pressing thereof. The size or length and width of the lugs and the size and profile of the dovetail groove vary depending on the size,
25 weight and stack length of the intended transformer assembly. For assembly of the transformer the

E-lamination pack 12 is placed in a jig, the windings 11 is placed on the centre limb of the E-laminations and the I-lamination pack is placed onto the E-lamination pack and is a loose fit thereon. Clamping force F is applied to urge the packs 12,14 into good mechanical contact, which is assisted if the I-pack 18 is torsionally flexible. Good mechanical contact avoids interruption of the magnetic flux path in the assembled core and hence loss of efficiency.

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An inwards deformation D (Figure 2b) is then caused by impact e.g. of appropriately profiled crimping fingers onto the ears 18 to seat them onto the dovetail formations and to fasten the E- and I-lamination packs 12, 14 together mechanically. Because of the dovetail formations, the act of deformation also pulls the I-stack 14 firmly against the E-stack 12. The resulting attachment between the lamination packs 12, 14 is sufficiently strong and permanent that no additional method of attachment is needed, through adhesive or other conventional means of holding the packs together may be employed if desired. The assembled transformer has the appearance shown in Figures 2a and 2c.

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In a variation (Figure 2d) the E-laminations 25 are

loose rather than adhered to one another in a pack and are held together by locator formations 26 of the bobbin 11. The laminations 25 are attached to a pack of I-laminations 27 as described above. The E-laminations can also be stacked laminations held together by one or more impingent pegs.

Figure 3 shows diagrammatically the transformer winding 11 and laminations 12, 14 in a jig 30 during assembly thereof, crimping blades 32 having angled end faces 34 impinging on the projections or ears 18 to bring about the required inward deformation thereof.

Various notch and ear profiles are shown in Figures 4a-4c. In Figure 4a the notch 16 is a plain dovetail and the ear 18a extends part way e.g. slightly over half way along it. In Figure 4b the dovetail surface of the notch 16b is doubly curved. In Figure 4c the notch 16c is again angular, but its lower face is inclined away from rather than parallel to the end face of the E-lamination 12 and the ear 18c extends substantially the whole way along the dovetail notch.

In Figure 5a the blade 32 has a plain inclined surface 34. The impact of blade 32 on the ear 18 both deforms the ear inwardly and causes a slight extension thereof as indicated by arrow 36. The angle between the working face of the dovetail notch 16 and a normal 38 to the end surface of the E-laminations 12 is advantageously above about 5° and may have whatever value is needed to bring about secure attachment of the lamination packs 12, 14. Angles above and below 5° may be used, the angle being selected in any individual case depending on the size and weight of the intended core structure. The arrangement of Figure 5b is similar except that the end face 34a of the blade 32a is ribbed as shown. In Figure 5c the blade 32b has an angled line of action to increase the component along the notch 16 and has a convexly curved end face 36b to maximise crimp and extrusion pressure on the ear 18.

In Figure 6 there are shown various possible core configurations. In Figure 6a there is shown a choke core having a pair of E-laminations 40 with an air-gap 42 between the central limbs 44. Figure 6b shows another choke core formed by a U-lamination 46 and a T-lamination 48. In Figure 6c a third choke core is

formed by E-lamination 50 and I-lamination 52. Figure 6d shows a transformer core formed by a pair of F-laminations 54. In this structure it will be noted that one of the laminations 54 has the notches or recesses 56 and the other has the clamping ears 58. Figure 6e shows a further transformer core formed by a U-lamination 60 and a T-lamination 62. In this structure, inclined surfaces 64 on the T-lamination 62 receive clamping ears 66 on the U-lamination 60.

In Figure 7 a structure is shown for a shaded pole electric motor having a rotor 70 that rotates in a stator defined by U-laminations 72. A pole bobbin 74 on lamination pack 76 is attached to by clamping ears and recesses as previously described.

In Figures 8a-8c there is shown an arrangement for an interleaved stack of E and I laminations 80,81. As seen in Figure 8c which shows the cut-lines on blank steel sheets the I-laminations 81 nest within the E-laminations 80 and can be cut from sheet by a progressive forming tool substantially without waste. The sides of the E-laminations 80 are formed with recesses 82 typically of semi-circular shape which, as seen in Figure 8b, alternate with the ears and recesses 16,18 in the assembled interleaved stack.

The ends 18a of the ears 18 are convexly curved to produce correspondingly curved recesses in the E-member 18. The curvature is selected to minimise disturbance to the flux path in the assembled transformer core. The I-laminations 81 have a single spigot and socket formation 83 for assembly into a torsionally flexible pack and the E-laminations 80 may have more than one spigot and socket connector 85 whose number and location is selected depending upon the size and other characteristics of the core being made.

In Figure 9 an I-lamination 90 fits to an E-lamination 92 to form a transformer core. The I-lamination 90 has depending projections or ears 94 offset slightly inwards from its ends 96 that fit into notches 98 in the end faces of the E-laminations 92. Assembly is by crimping inwards the thin material of the outer faces of the notches 98 as shown by arrows 100 using crimping blades, of the kind previously described. In Figure 10 a "Unilam" (registered Trade Mark) type core is formed in which an E-lamination 102 having an extended side limb 104 receives an abbreviated I-lamination 106. The E-lamination 102 has a slot 103 in the inner side face of its extended side limb 104 and a slot 108 in the end face of its other side limb that receive

corresponding projections or ears on the I-laminations 106. It will be noted that the slots 103, 108 and the corresponding lines of action of the necessary crimping blades are directed generally at right angles to one another as shown by arrows 110, 112.

Details of the possible slot and ear formations of the I- and E-laminations are shown in Figures 11, 11a and 12, 12a which are respectively before and after deformation. In Figure 11a the dovetail surface 111 is formed on the deformable outer portion of the slot 98 and in Figure 12a it is formed at 114 on the outer surface of ear 94.

It will be appreciated that the fastening system described above has a number of advantages. It enables a core from an electromagnetic device to be assembled rapidly and inexpensively. The laminations can be made nearly without waste. The method can be used for assembly of loose lamination transformers and stacked lamination transformers or transformers having laminations which are partly stacked and partly loose or inter-leaved lamination transformers. Tests have shown that the efficiency of an assembled core according to the invention is substantially the same

as or only slightly less than that of a conventionally assembled core.

5 Figures 13 and 13a show a yet further profile for a slot and ear which can be used when high retaining force is required. One pack of laminations has an ear 120 having a convex blind face 122 which is deformable into contact with a concavity 124 in the other pack of laminations 126. The convex blind face 122 initially
10 passes face 125 of lamination 126 with clearance but after deformation mechanically interlocks therewith.



18.

CLAIMS:

1. A lamination assembly for an electromagnetic device comprising first and second packs of complementary laminations that fit together and have interfitting formations, the formations of one of the packs of laminations being projections that are permanently deformed inwardly towards the complementary formations of the other pack of laminations so as to permanently fasten the first and second packs of laminations together.

2. The assembly of claim 1 wherein the deformation of the projections gives rise to a clamping force which frictionally holds the first and second packs together.

3. The assembly of claim 1, where the deformation of the projections establishes a mechanical lock that holds the first and second packs of laminations together.



19.

5 4. The assembly of claim 3, where the interfitting formations of the first and second packs are profiled so that deformation of said formations positively urges the first and second packs of laminations together.

10 5. A lamination assembly according to claim 3 or 4, where said first pack of laminations includes at least one external face with a dovetail formation therein, and said second pack of laminations includes at least one deformable projection thereon and each said deformable projection is bent inwardly toward and permanently engages said respective dovetail formation and thereby permanently locks said first and second
15 packs of laminations together.

20 6. A lamination assembly according to any preceding claim, wherein each said projection has a width and a length, with the length being greater than the width.

7. A lamination assembly according to any preceding claim, wherein adjacent laminations of the first pack



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are fastened together and adjacent laminations of the second pack are fastened together.

5 8. A lamination assembly according to any preceding claim, wherein at least one of the packs of laminations is torsionally flexible.

10 9. A lamination assembly according to claim 8, wherein each lamination of the or each torsionally flexible pack is connected to an adjacent lamination by a single connection.

15 10. A lamination assembly according to claim 9, wherein each lamination of the or each torsionally flexible pack comprises, on a common axis perpendicular to the lamination, a single depression on one side thereof and a single projection on the other side thereof, each lamination being coupled to an adjacent lamination only by the single projection
20 projecting into the single depression of the adjacent lamination.



21.

11. A lamination assembly according to any preceding claim, wherein the external surface of each said projection is directed inwardly at an angle of at least 5° to the respective exterior face of the pack of laminations.

12. A lamination assembly according to any preceding claim, wherein at least one of the first and second packs includes E-laminations.

13. A lamination assembly according to any preceding claim, wherein at least one of the first and second packs includes I-laminations.

14. A lamination assembly according to any preceding claim, wherein at least one of the first and second packs includes U-laminations.

15. A lamination assembly according to any of claims 1-11, wherein at least one of the first and second packs includes F-laminations.



22.

16. A lamination assembly according to any one of claims 1 to 13, wherein said first pack of laminations is a pack of E-laminations and said second pack of laminations is a pack of I-laminations.

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17. A lamination assembly according to claim 13 or 16, wherein said pack of I-laminations is torsionally flexible about an axis perpendicular to the laminations.

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18. A lamination assembly according to claim 6, wherein said length is at least approximately 1.5 times greater than said width.

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19. A lamination assembly substantially as hereinbefore described with reference to the accompanying drawings.

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20. A transformer, choke or electric motor having a lamination assembly as claimed in any preceding claim.



23.

21. A method of assembling packs of laminations of an electromagnetic device, which comprises:

providing first and second packs of complementary laminations that fit together and have interfitting formations;

holding the first and second packs of laminations positively together in mechanical contact; and

deforming said formations on one or both of the packs of laminations to engage the formations of the other pack of laminations to clamp the first and second packs of laminations together.

22. A method according to claim 21, wherein the interfitting formations of the first and second packs of laminations are profiled so that deformation of said formations mechanically fastens the first and second packs together.

23. A method according to claim 22, wherein the interfitting formations of the first and second packs of laminations are profiled so that deformation of said formations positively urges the first and second packs of laminations together.



24.

24. A method according to any of claims 21 to 23,
wherein a lamination of said first pack and a
lamination of said second pack are stamped from a
single sheet, the pattern for forming said laminations
5 being such that one lamination is formed nested within
the other so that they can be stamped from said sheet
substantially without waste.

25. A method according to any one of claims 21 to 24,
10 including the steps of fastening together adjacent
laminations of the first pack of laminations and
fastening together adjacent laminations of the second
pack of laminations.

15 26. A method according to any of claims 21 to 25,
wherein the first pack of laminations is rigid and the
second pack of laminations is torsionally flexible
about an axis perpendicular to the planes of the
laminations whereby during assembly the second pack of
20 laminations flexes to accommodate irregularities in
the first pack of laminations and good mechanical and
magnetic contact between the first and second packs
is obtained.



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27. A method according to claim 26, wherein the laminations of the first pack are E-laminations and those of the second pack are I-laminations.

5 28. A method of assembling packs of laminations of an electromagnetic device substantially as hereinbefore described with reference to the accompanying drawings.

10 29. A transformer, choke or electric motor having laminations assembled by a method as claimed in any one of claims 21 to 28.

15 30. First and second packs of laminations when provided as a set for assembly into a lamination assembly for an electromagnetic device as claimed in any of claims 1-20 or 29, said first and second packs of complementary laminations having the ability to fit together and having interfitting formations, the
20 formations of one of the packs of laminations being projections that are permanently deformable inwardly towards the complementary formations of the other pack of laminations so as, after assembly, to permanently



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fasten the first and second packs of laminations together.

5 31. The first and second packs of claim 30, wherein after assembly, the deformation of the projections gives rise to a clamping force which frictionally holds the first and second packs together.

10 32. The first and second packs of claim 30, wherein after assembly the deformation of the projections establishes a mechanical lock that holds the first and second packs of laminations together.

15 33. The first and second packs of claim 30, wherein after assembly the interfitting formations of the first and second packs are profiled so that deformation of said formations positively urges the first and second packs of laminations together.

20 34. The first and second packs according to claim 32 or 33, where said first pack of laminations includes at least one external face with a dovetail formation therein, and said second pack of laminations includes at least one deformable projection thereon and each



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said deformable projection is bent inwardly toward and permanently engages said respective dovetail formation and thereby permanently locks said first and second packs of laminations together.

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35. The first and second packs according to any of claims 30-34, wherein each said projection has a width and a length, with the length being greater than the width.

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36. The first and second packs according to any of claims 30-35, wherein adjacent laminations of the first pack are fastened together and adjacent laminations of the second pack are fastened together.

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37. The first and second packs according to any of claims 30-36, wherein at least one of the packs of laminations is torsionally flexible.

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38. The first and second packs according to claim 37, wherein each lamination of the or each torsionally flexible pack is connected to an adjacent lamination by a single connection.



28.

39. The first and second packs according to claim 38, wherein each lamination of the or each torsionally flexible pack comprises, on a common axis perpendicular to the lamination, a single depression on one side thereof and a single projection on the other side thereof, each lamination being coupled to an adjacent lamination only by the single projection projecting into the single depression of the adjacent lamination.

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40. The first and second packs according to any of claims 30-39, wherein the external surface of each said projection is directed inwardly at an angle of at least 5° to the respective exterior face of the pack of laminations.

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41. The first and second packs according to any of claims 30-40, wherein at least one of the first and second packs includes E-laminations.

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42. The first and second packs according to any of claims 30-41, wherein at least one of the first and second packs includes I-laminations.



29.

43. The first and second packs according to any of claims 30-40, wherein at least one of the first and second packs includes U-laminations.

5 44. The first and second packs according to any of claims 30-40, wherein at least one of the first and second packs includes F-laminations.

10 45. The first and second packs according to any one of claims 30 to 42, wherein said first pack of laminations is a pack of E-laminations and said second pack of laminations is a pack of I-laminations.

15 46. The first and second packs according to claim 42 or 45, wherein said pack of I-laminations is torsionally flexible about an axis perpendicular to the laminations.

20 47. The first and second packs according to claim 35, wherein said length is at least approximately 1.5 times greater than said width.
