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(54) **A MAGNETIC POWER UNIT**

(57) The magnetic poser unit (100) comprises a magnetic core (10) including a first, a second and a third winding channels (2a, 2b, 2c) respectively arranged around a first, a second and a third crossing axis (A-A, B-B, C-C) orthogonal to each other, each of said winding channels (2a, 2b, 2c) being intended for receiving one coil wound around the magnetic core (10), each coil having at least one turn. The crossing axis (A-A, B-B, C-C) define orthogonal planes providing eight octants, each including

a protrusion defining a protruding spacer (20), being spaced to each other by said winding channels (2a, 2b, 2c). The magnetic core (10) is a composed core formed by several different partial magnetic cores assembled together including two side partial magnetic cores (12), each including four protruding spacers (20). The magnetic core (10) further includes a through hole (30) housing a device for heat dissipation (50).

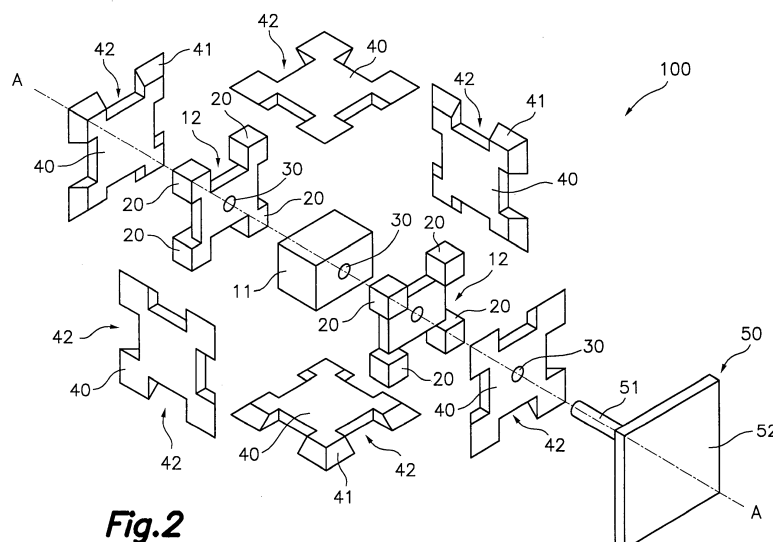


Fig.2

Description

Technical field

[0001] The present invention refers to a reduced size integrated magnetic power unit comprising a magnetic core generally including a first, a second and a third winding channels respectively arranged around a first, a second and a third intersecting axis orthogonal to each other, each of said winding channels intended for receiving at least one coil wound around the magnetic core each coil having at least one turn.

[0002] The proposed magnetic power unit is particularly adapted to be used for example as a transformer or inductor in the electrical power field, and suitable for operating a high power electrical device, especially usable in the field of hybrid and electrical vehicles (HEVs) that nowadays is growing quite fast. The new models of electrical vehicle require more and more power electronics inside, not only for the electrical motor supply with speed and torque control, but also for high-voltage (HV) battery chargers and stable incar continuous low-voltage (LV) power supplies.

[0003] The magnetic power unit of this invention responds to a new volumetric efficiency concept on magnetic units with a magnetic core including around it orthogonal windings for producing two or three substantially orthogonal magnetic fields at all point within the core

[0004] It will be understood along this description that references to geometric position, such as parallel, perpendicular, tangent, etc. allow deviations up to $\pm 5^\circ$ from the theoretical position defined by this nomenclature. It will also be understood that any range of values given may not be optimal in extreme values and may require adaptations of the invention to these extreme values are applicable, such adaptations being within reach of a skilled person.

Background of the invention

[0005] US 4210859 discloses an inductive device that may be utilized as an inductor or transformer in a variety of applications, comprising a magnetic core and orthogonal windings for producing two or three substantially orthogonal magnetic fields at all point within the core. Figs. 16 and 17 of this patent document disclose embodiments for inductive device structures which accommodate several orthogonal windings on the same core. However, this disclosure, when detailing a triaxial inductive device does not solve at least two problems related to the construction of the core and the self-heating of the inductor, when this is or is associated to a transformer, the last problem making the proposal practically unfeasible, mainly when operating under high power.

[0006] The invention solves the above problems by a special construction of the core and by including associated means for an effective heat dissipation. In this way, it is obtained a highly magnetic power unit up to 50%

smaller than the average size of other known magnetic units and with a power density increasing up to 200W/cm³...

[0007] The teaching of this invention provides a magnetic unit that can be implemented in one or more transformers or one or more inductors and/or combinations of magnetically coupled or uncoupled transformers and inductors.

Disclosure of the invention

[0008] The invention provides a highly compact magnetic power unit comprising a magnetic core that includes a first, a second and a third winding channels respectively arranged around a first, a second and a third crossing axis orthogonal to each other, each of said winding channels being intended for receiving at least one coil wound around the magnetic core, each coil having at least one turn. The said first, second and third crossing axis define orthogonal planes providing eight octants, each including a protrusion defining a protruding spacer said protruding spacers being spaced to each other by said winding channels. Fig. 17 of US 4210859 discloses such a core in a single piece.

[0009] According to the invention the magnetic core is formed by at least two different partial magnetic cores assembled together by an attachment as a composed core in a layered configuration, including two side partial magnetic cores each including four protruding spacers and the magnetic core includes a through hole or cavity associated to a device for heat dissipation housed inside. The through hole for heat dissipation is perpendicular to one of said first, second or third planes, and extends through at least two partial magnetic cores.

[0010] The device for heat dissipation include a non-electrical conductor, magnetic or non-magnetic, paramagnetic or diamagnetic heat pipe arranged in said through hole and communicated with a heat dissipation plate. In a preferred embodiment, the heat pipe is a hollow pipe filled with a fluid with a low boiling point (as per a technique known in the art).

[0011] In a first embodiment, the composed core includes at least one additional central partial magnetic core lacking of protruding spacers interposed between said two side partial magnetic cores, i.e. the core is made of three pieces. The partial magnetic cores are assembled together through a mechanical joint attachment using auxiliary elements or alternatively they are assembled together through an adhesive.

[0012] In an embodiment, the composed core has a general geometric shape selected among a rectangular parallelepiped, cube or sphere.

[0013] The magnetic power unit according to the disclosed structured is further surrounded by flux closing magnetic covers. In an embodiment, each flux closing cover is in contact with two or four flux closing covers perpendiculars to it, through perimeter faces. Also in an embodiment, the cited perimeter faces are bevelled. Fur-

thermore, each flux closing cover includes four notches providing winding connection windows when the flux closing covers are in contact with the protruding spacers.

[0014] In an embodiment, the core is a rectangular parallelepiped and the flux closing covers are constituted by two or three pairs of flux closing covers, wherein each pair of covers is arranged at two opposite sides of the composed magnetic core, each cover being in contact with four different protruding spacers.

[0015] In an alternative embodiment that has not been illustrated (but that will be equivalent to the one in Fig. 16 of US 4210859) the composed magnetic core has a general geometric shape of a sphere and the flux closing covers are constituted by at least two opposed spherical caps, and each flux closing cover is in contact with four different protruding spacers.

[0016] The composed magnetic core here disclosed and/or the flux closing covers (are made of a material selected among ferrite, ferromagnetic material, or a PBM (polymer-bonded soft magnetic material) injectable material.

[0017] The proposed magnetic power unit can be implemented under different embodiments being any of:

- a transformer comprising three coils wound in three respective orthogonal axes;
- a transformer comprising two coils wound in two respective orthogonal axes, a third orthogonal axis without coil or including a choke;
- a choke comprising three coils wound in three respective orthogonal axes or comprising two coils wound in two respective axes;
- a transformer including three coils in each of the three axes, or any combination of transformer and choke arranged among the three axes either magnetically coupled or uncoupled.

Brief description of the drawings

[0018] Other features of the invention appear from the following detailed description of some embodiments regarding the accompanying drawings, in which:

Fig. 1 shows a perspective view of a magnetic power unit according to an embodiment of the present invention;

Fig. 2 shows an exploded view of a magnetic power unit according to a particular embodiment of the present invention;

Fig. 3 shows a partial exploded view of the magnetic power unit of Fig. 2;

Fig. 4 shows schematically the arrangement of three coils wound around the magnetic power unit of Fig. 1;

Fig. 5 shows a perspective view of a magnetic power unit according to a particular embodiment of the present invention;

Fig. 6 shows an exploded view of a magnetic power unit according to a particular embodiment of the

present invention; and

Fig. 7 shows a perspective view of a magnetic power unit according to a particular embodiment of the present invention.

Detailed description of some embodiments

[0019] Figure 1 shows a magnetic power unit 100 according to a particular embodiment of the present invention. The magnetic power unit 100 comprises a magnetic core 10 including a first, a second and a third winding channel 2a, 2b, 2c, respectively arranged around a first, a second and a third axis A-A, B-B, C-C orthogonal to each other. Each winding channel 2a, 2b, 2c is intended for receiving at least one coil, having at least one turn, wound around the magnetic core 10. Depending on the number and on the arrangement of one or more coils wound around one or more winding channels 2a, 2b, 2c, the magnetic power unit 100 provides different working configurations that will be discussed with greater details in the following description.

[0020] The three axes are pairwise perpendicular and define a first, a second and a third plane in which the winding channels are located respectively. For example, the first winding channel 2a, that is arranged around the first axis A-A, is located in the first plane that is defined by the other two axis B-B and C-C (i.e. the first plane is the plane orthogonal to the first axis A-A and on which the axes B-B and C-C lie).

[0021] The three planes define eight octants, each including a protrusion defining a protruding spacer 20. The eight protruding spacers 20 are spaced to each other by the winding channels 2a, 2b, 2c.

[0022] The magnetic core 10 is formed by a plurality of different partial magnetic cores 11, 12 made of a magnetic material selected among ferrite, ferromagnetic material, or a Polymer Bonded Soft Magnetic (PBSM) injectable material. The partial magnetic cores are assembled together by an attachment (for example by an adhesive) forming a composed core 10 in a layered configuration (i.e. the partial magnetic cores are stacked to each other).

[0023] With respect to figure 1, the magnetic core 10 is preferably formed by three different partial magnetic cores comprising a central partial magnetic core 11 and two side partial magnetic cores 12, wherein each of the two side partial magnetic cores 12 includes four protruding spacers 20. The central partial magnetic core 11 is interposed between the two-side partial magnetic cores 12 and lacks of protruding spacers 20. In this embodiment, the two-side partial magnetic cores 12 have a substantially flat surface configured to be attached to the central partial magnetic core 11 by means of an adhesive (not shown and having a thickness negligible with respect to the dimensions of the magnetic core 10).

[0024] Preferably, the composed core 10, when assembled, has a general geometric shape of a rectangular parallelepiped or a cube. In this case, as shown in figure

1 each protruding spacer 20 has a general geometric shape substantially cubic shape. An alternative embodiment (not shown) can provide that the composed core 10, when assembled, has a general geometric shape of a sphere. In this last case, each protruding spacer 20 has a general geometric shape comprising an external surface rounded.

[0025] Some embodiments can provide that the magnetic core 10 is formed by only two partial magnetic cores each having the protruding spacers 20 (for example two half partial magnetic cores having the same shape and configured to be assembled symmetrically), or by more than three partial magnetic cores. In this last case, the magnetic core 10 is preferably formed by two side partial magnetic cores 12, each including four protruding spacers 20, and a plurality of central partial magnetic cores 11 lacking of protruding spacers 20 stacked to each other.

[0026] In general, the magnetic core 10 is formed by at least two different partial magnetic cores assembled together by an attachment and comprising two side partial magnetic cores 12, each having four protruding spacers 20. Preferably, the magnetic core 10 includes at least one additional central partial magnetic core 11 lacking of protruding spacers 20 interposed between the two-side partial magnetic cores 12.

[0027] With respect to figures 1 and 2, the magnetic core 10 includes a through hole 30 associated to a device for heat dissipation 50. The through hole 30 is preferably perpendicular to one of the first, second or third planes, more preferably the through hole is substantially coaxial with one of the first, second or third axis. With respect to figure 2 the through hole 30 extends through the two-partial side magnetic cores 12 and consequently through the central partial magnetic core 11.

[0028] The device for heat dissipation 50 includes a heat dissipation pipe 51 made of a thermal conductor material, preferably made of a non-electrical conductor material. The heat dissipation pipe 51 is arranged in the through hole 30 and connected to a heat dissipation plate 52, made preferably of the same material of which the dissipation pipe is made. More preferably, the heat dissipation pipe 51 is a hollow pipe filled with a fluid. Some embodiment can provide that the dissipation pipe 51 is made of magnetic or non-magnetic material, or made of paramagnetic or diamagnetic material.

[0029] As shown in figure 2, the magnetic power unit 100 is preferably surrounded by flux closing magnetic covers 40 preferably made of a material selected among ferrite, ferromagnetic material, or a Polymer Bonded Soft Magnetic (PBSM) injectable material, more preferably the same material of which the composed magnetic core 10 is made. In this embodiment, the through hole 30 extends also through the flux closing magnetic covers 40, so that the dissipation pipe 51 can pass through the composed magnetic core 10 and the heat dissipation plate can be arranged externally to the flux closing magnetic covers 40.

[0030] In the case of a composed magnetic core 10

having a general geometric shape of a rectangular parallelepiped or a cube, the flux closing covers 40 are preferably constituted by three pairs of flux closing covers 40, arranged at the opposite sides of the magnetic core 10. With respect to figure 3, each cover 40 is in contact (for example attached by means of adhesive) with four protruding members 20 and is spaced from the central partial magnetic core 11.

[0031] Preferably, each flux closing cover 40 is in contact with other four flux closing covers 40 perpendiculars to it, through four perimeter faces 41. With respect to figure 3, the perimeter faces 41 are advantageously bevelled i.e. tapered towards the magnetic core 10 with an inclined coupling surface forming a truncated pyramid having preferably with a surface inclined of about 45°. In this way, in the case of magnetic core 10 having a general geometric shape of a cube (as shown in figure 2), covers 40 can be all realized with the same shape.

[0032] An alternative embodiment, not shown, can provide that the composed magnetic core 10 has a general geometric shape of a sphere. In this case, the flux closing covers 40 are constituted by at least two opposed spherical caps, and each flux closing cover is in contact (for example attached by means of adhesive) with four different protruding spacers 20.

[0033] Figure 4 shows three coils 70a, 70b, 70c wound around the three winding channels 2a, 2b, 2c of the composed magnetic core 10 shown in figure 1, respectively. In this embodiment, the magnetic power unit 100 provides a transformer comprising three coils 70a, 70b, 70c wound around the three-respective axis A-A, B-B, C-C orthogonal to each other, but as mentioned above, depending on the number and on the arrangement of one or more coils wound around the composed magnetic core 10, the magnetic power unit 100 may provide different device configurations.

[0034] In figure 4 the through hole 30 is not shown for a better clarity of the arrangement of the three coils 70a, 70b, 70c. It is intended that the turns of the coils 70b and 70c wound around the winding channels 2b and 2c are arranged for avoiding the hole 30 for allowing the passage of the heat dissipation pipe 51.

[0035] Some embodiments may provide that the magnetic power unit 100 is a transformer having two coils wound around two respective winding channels (i.e. arranged around two respective axes) and the third winding channel without coil. Furthermore, a third coil wound around the third winding channel may provide a choke for the transformer formed by the two coils wound around the other two winding channel.

[0036] Some embodiment may provide that the magnetic power unit 100 is a choke comprising three coils wound in the three-respective winding channel, or comprising two coils wound around two respective winding channels.

[0037] With respect to figure 5, another embodiment of the magnetic power unit 100 according to the present invention is shown. In this embodiment, the composed

magnetic core 10 is formed by three different partial magnetic cores comprising a central partial magnetic core 11 and two side partial magnetic cores 12, wherein each of the two-side partial magnetic cores 12 includes four protruding spacers 20. The central partial magnetic core 11 is interposed between the two-side partial magnetic cores 12 and lacks of protruding spacers 20. Unlike the embodiment shown in figures 1-4, this embodiment provides that the two-side partial magnetic cores 12 have a substantially flat surface configured to be arranged toward the outside of the magnetic core 10 when it is assembled.

[0038] With respect to figure 6, the partial magnetic cores 11, 12 are preferably assembled together by means of a mechanical joint attachment using auxiliary elements 60a, 60b comprising preferably a pair of coupling members 60a, 60b each having a substantially C-shaped conformation. In particular, each coupling member 60a, 60b comprises a first wall 61 and two second walls 62 extending from two opposite sides of the first wall 61 towards an orthogonal direction with respect to the first wall. The ends of the two second walls 62 of a coupling member 60a, 60b are configured to snap with the first wall 61 of the other coupling member 60b, 60a.

[0039] In this embodiment, the central partial magnetic core 11 is surrounded by six walls of the auxiliary elements 60 (the first walls and second walls of the coupling members 60a, 60b). The first wall 61 of each coupling member 60a, 60b is provided with an opening 63, for passing the heat dissipation pipe 51 through the hole 30, and a sleeve 64 arranged around the opening 63. The end 65 of sleeves 64 are configured to snap with the flat surface of the side partial magnetic cores 12 when the composed magnetic core 10 is assembled.

[0040] Preferably, the walls 61, 62 of each coupling member 60a, 60b are provided with a plurality of notches configured to leave open a plurality of passages for allow a direct contact between the central partial magnetic core 10 and the protruding spacers 20 of the side partial magnetic cores 12.

[0041] More preferably, the coupling members 60a, 60b are conformed for providing eight passages to allow a direct contact between each of the eight corners of the central partial magnetic core 10 with each of the protruding spacers 20 of the side partial magnetic cores 12, respectively. In this last embodiment, each protruding spacer 20 is preferably provided with a seat having a shape complementary to the respective corner.

[0042] As shown in figure 6, the magnetic power unit 100 is preferably surrounded by flux closing magnetic covers 40 preferably made of a material selected among ferrite, ferromagnetic material, or a Polymer Bonded Soft Magnetic (PBSM) injectable material, more preferably the same material of which the composed magnetic core 10 is made.

[0043] In this embodiment, the flux closing covers 40 are preferably constituted by two pairs of flux closing covers 40, arranged at the opposite sides of the magnetic core 10 and orthogonally with respect to the side partial

magnetic covers 12. Each cover 40 is in contact (for example attached by means of adhesive) with four protruding members 20 and is spaced from the central partial magnetic core 11.

[0044] With respect to figures 2, 3, 6 and 7, each flux closing cover 40 includes four notches 42, each notch 42 for providing winding connection windows when flux closing covers 40 are in contact with the protruding spacers 20.

Claims

1. A magnetic power unit (100) comprising a magnetic core (10) including a first, a second and a third winding channels (2a, 2b, 2c) respectively arranged around a first, a second and a third crossing axis (A-A, B-B, C-C) orthogonal to each other, each of said winding channels (2a, 2b, 2c) being intended for receiving at least one coil wound around the magnetic core (10), each coil having at least one turn, wherein said first, second and third crossing axis define orthogonal planes providing eight octants, each including a protrusion defining a protruding spacer (20), said protruding spacers (20) being spaced to each other by said winding channels (2a, 2b, 2c), **characterized in that** the magnetic core (10) is formed by at least two different partial magnetic cores assembled together by an attachment as a composed core in a layered configuration, including two side partial magnetic cores (12), each including four protruding spacers (20), wherein said magnetic core (10) includes a through hole (30) associated to a device for heat dissipation (50).
2. The magnetic power unit (100) according to claim 1, wherein said composed core include at least one additional central partial magnetic core (11) lacking of protruding spacers interposed between said two side partial magnetic cores (12).
3. The magnetic power unit (100) according to claim 1 or 2, wherein said device for heat dissipation (50) include a non-electrical conductor, magnetic or non-magnetic, paramagnetic or diamagnetic heat dissipation pipe (51) arranged in said trough hole (30) and communicated with a heat dissipation plate (52).
4. The magnetic power unit according to claim 3, wherein said through hole (30) for heat dissipation is perpendicular to one of said first, second or third planes, and extends through at least two partial magnetic cores (11, 12).
5. The magnetic power unit (100) according to any of preceding claims, wherein the composed core (10) has a general geometric shape selected among a

rectangular parallelepiped, cube or sphere.

6. The magnetic power unit (100) according to claim 5, wherein said partial magnetic cores (11, 12) are assembled together through a mechanical joint attachment using auxiliary elements (60a, 60b). 5
7. The magnetic power unit (100) according to claim 5, wherein said partial magnetic cores (11, 12) are assembled together through an adhesive. 10
8. The magnetic power unit (100) according to any preceding claim, wherein the magnetic power unit is surrounded by flux closing magnetic covers (40). 15
9. The Magnetic power unit (100) according to claim 8, wherein the magnetic core (10) is a rectangular parallelepiped and the flux closing covers (40) are constituted by two or three pairs of flux closing covers, wherein each pair of covers is arranged at two opposite sides of the composed magnetic core, each cover (40) being in contact with four different protruding spacers (20). 20
10. The magnetic power unit (100) according to claim 8 wherein the composed magnetic core (10) has a general geometric shape of a sphere and the flux closing covers (40) are constituted by at least two opposed spherical caps, and each flux closing cover is in contact with four different protruding spacers (20). 25 30
11. The magnetic power unit (100) according to claim 8 or 9 wherein each flux closing cover (40) is in contact with two or four flux closing covers (40) perpendicular to it, through perimeter faces (41). 35
12. The magnetic power unit (100) according to claim 11 wherein said perimeter faces (41) are bevelled. 40
13. The magnetic power unit (100) according to claims 11 or 12 wherein each flux closing cover (40) includes four notches (42), for providing winding connection windows when the flux closing cover (40) are in contact with the protruding spacers (20). 45
14. The magnetic power unit (100) according to claim 3, wherein said heat pipe (51) is a hollow pipe filled with a fluid with a low boiling point. 50
15. The magnetic power unit (100) according to claim 1 being any of: 55
 - a transformer comprising three coils wound in three respective axis;
 - a transformer comprising two coils wound in two respective axis, a third axis without coil or including a choke;

- a choke comprising three coils wound in three respective axis or comprising two coils wound in two respective axis;
 - a transformer including three coils in each of the three axis, or any combination of transformer and choke arranged among the three axis.

16. The magnetic power unit (100) according to claim 8 wherein the composed magnetic core (10) and/or the flux closing covers (40) are made of a material selected among ferrite, ferromagnetic material, or a PBM injectable material.

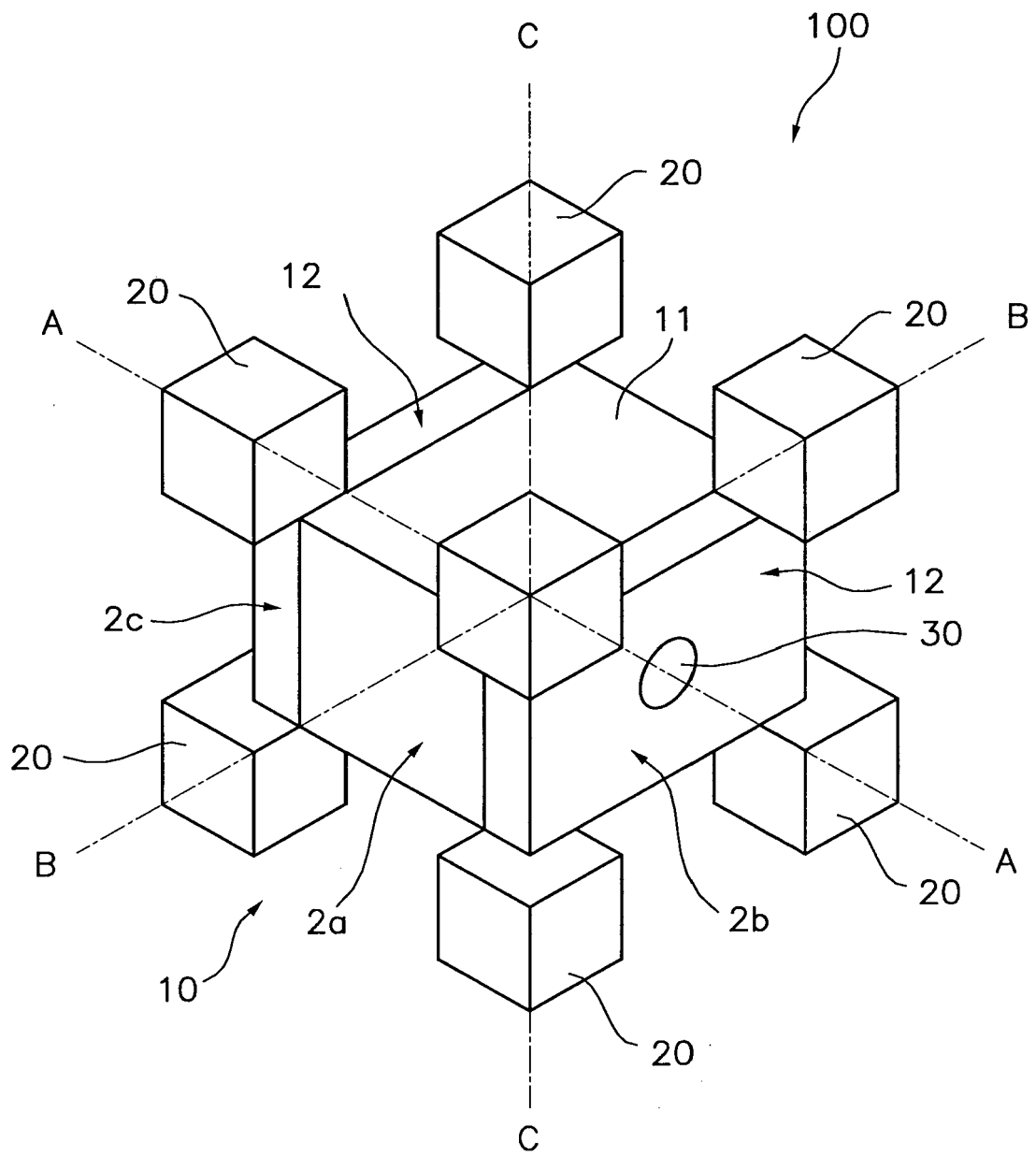


Fig. 1

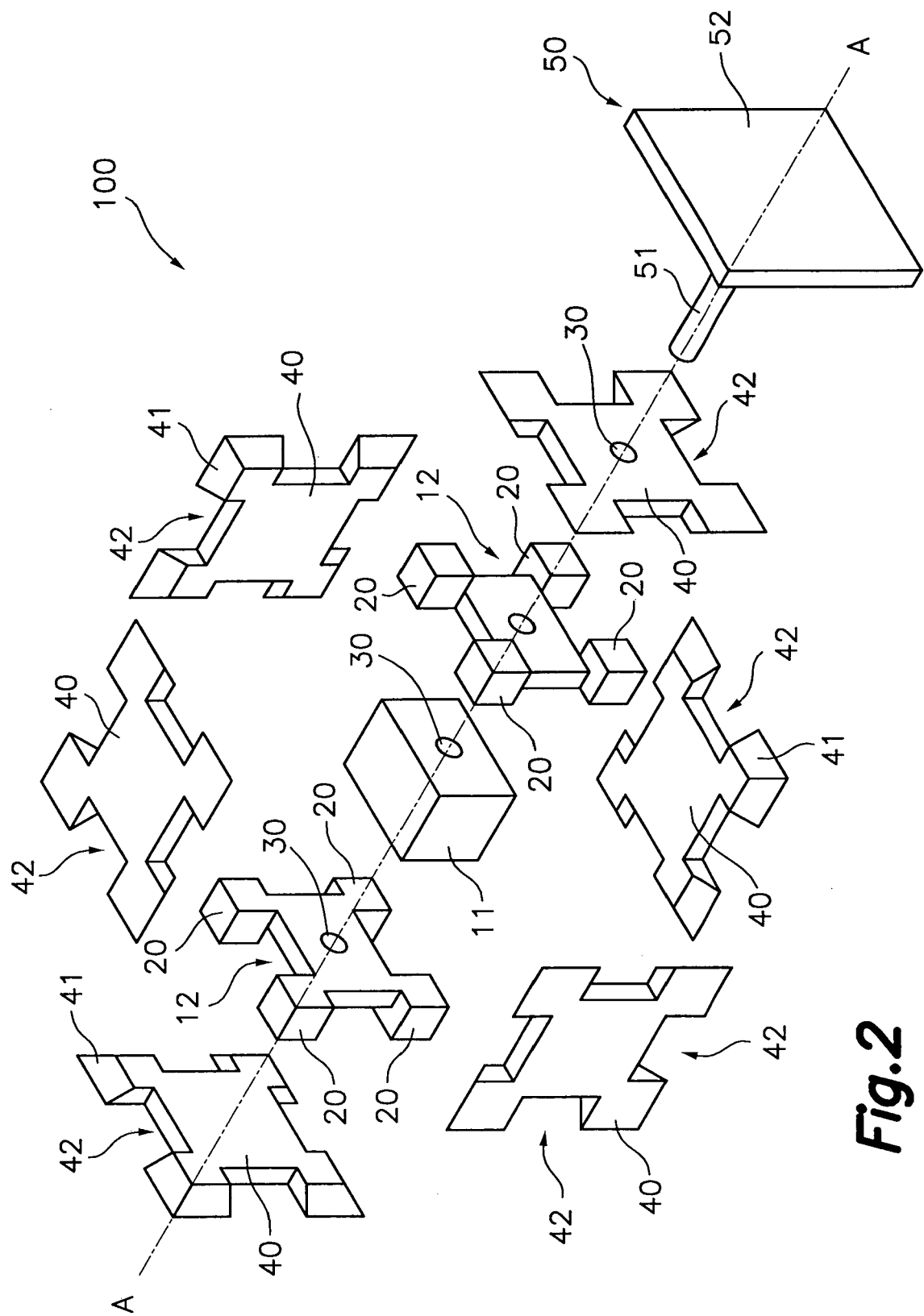
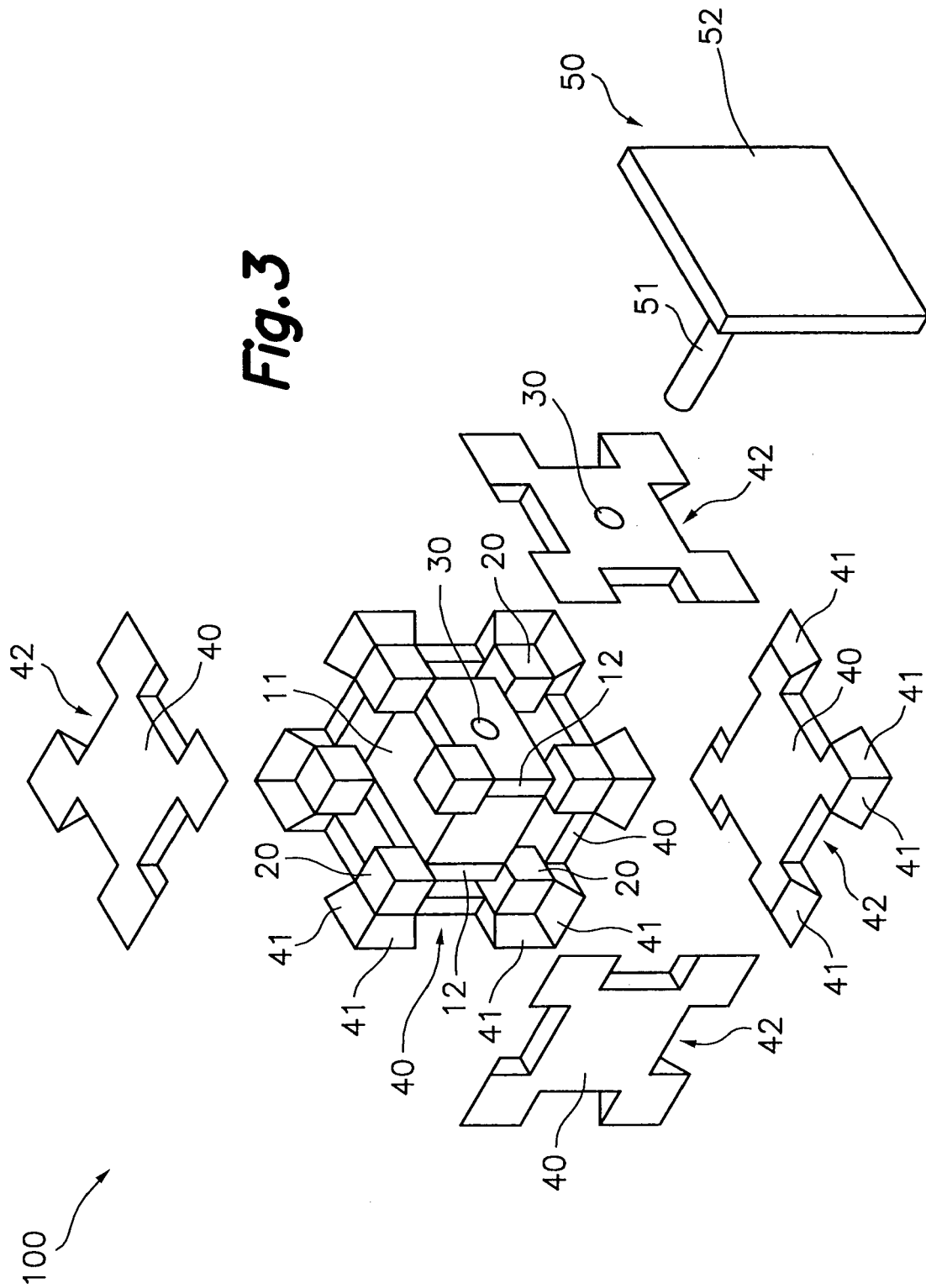


Fig. 2



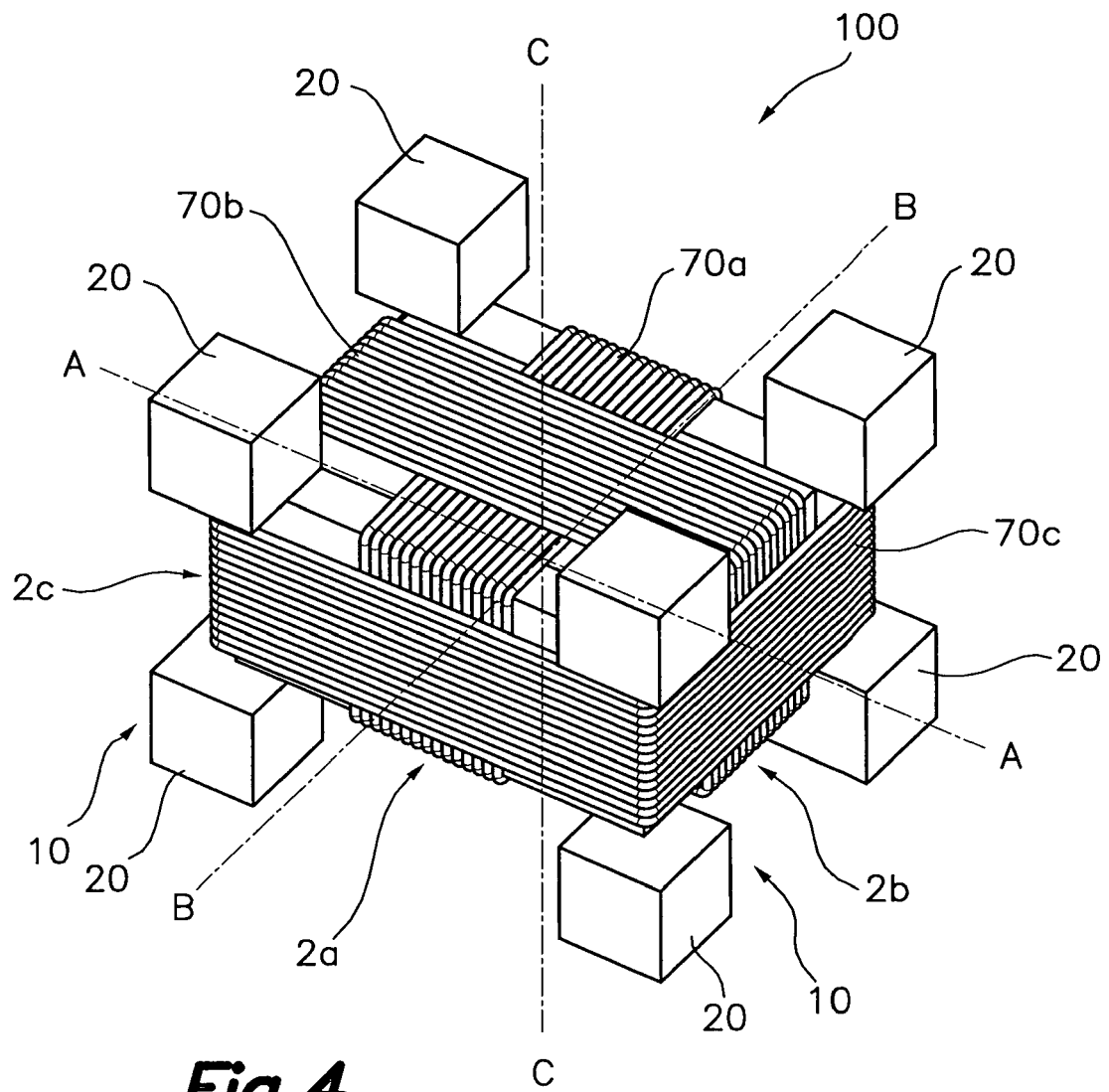


Fig.4

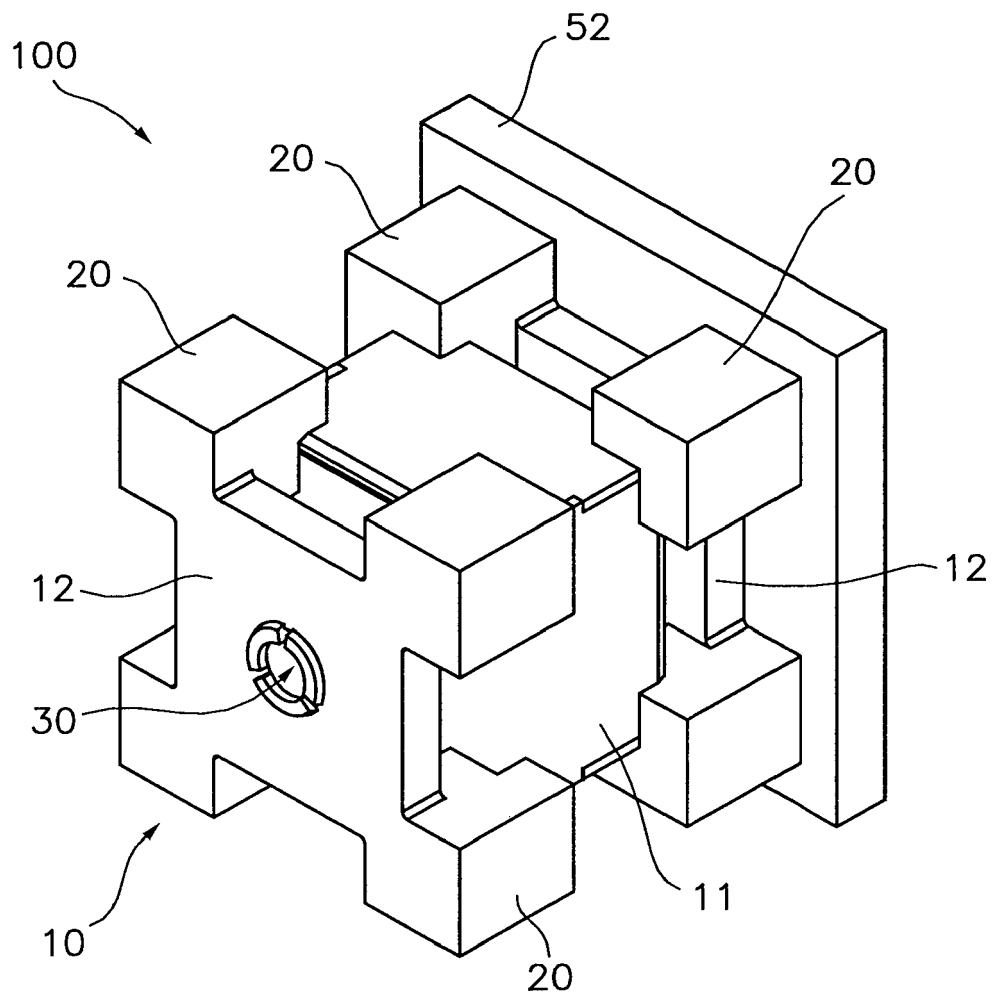


Fig.5

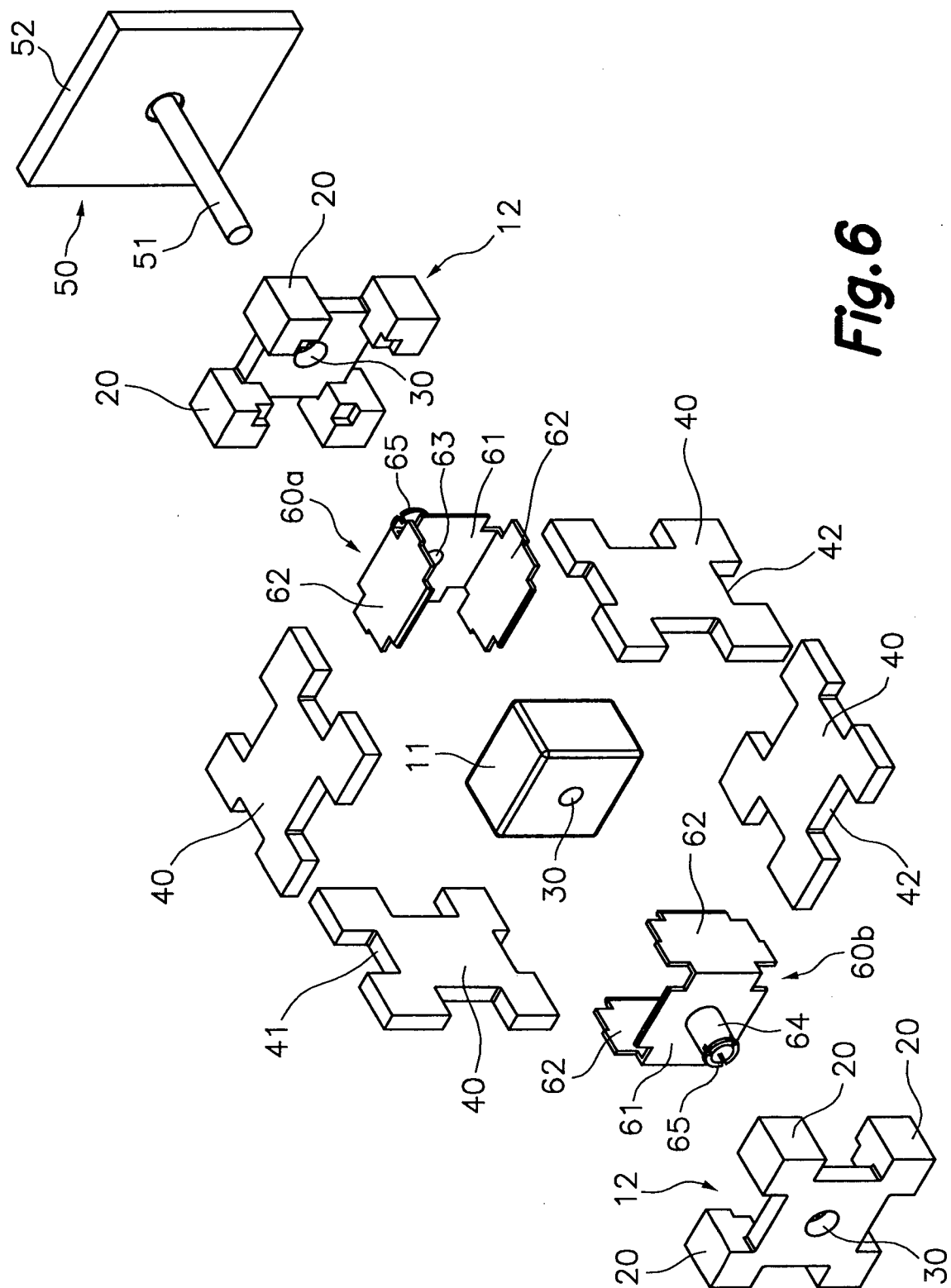


Fig. 6

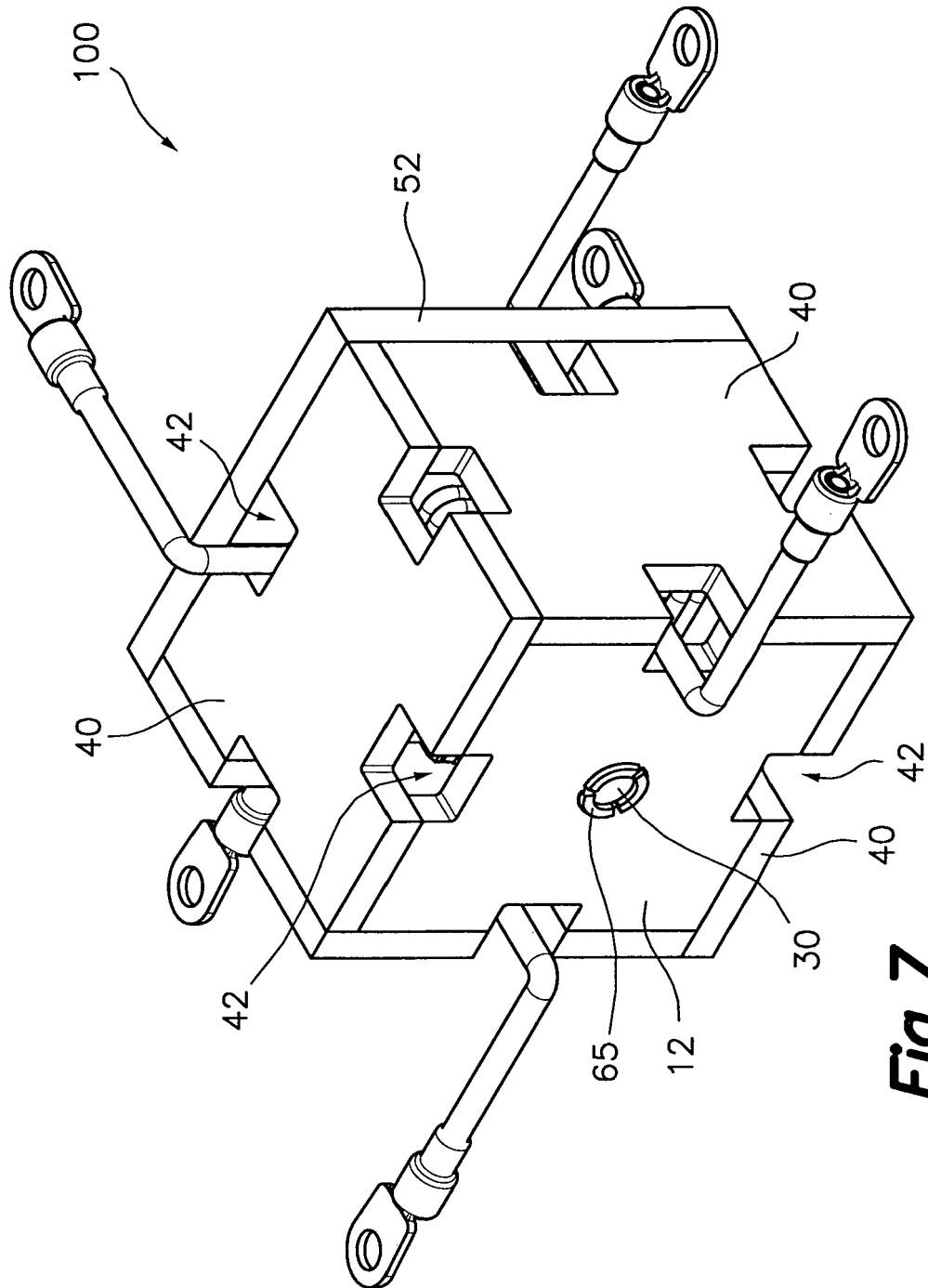


Fig. 7



EUROPEAN SEARCH REPORT

 Application Number
EP 16 00 2348

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EUROPEAN SEARCH REPORT

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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