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(72) Inventors:
• **DASZKIEWICZ, Robert**
91-852 Lodz (PL)
• **KLYS, Pawel**
93-008 Lodz (PL)
• **CAL, Jerzy**
94-056 Lodz (PL)
• **WADON, Lukasz**
91-518 Lodz (PL)

(71) Applicant: **Hitachi Energy Ltd**
8050 Zürich (CH)

(74) Representative: **Vossius & Partner**
Patentanwälte Rechtsanwälte mbB
Siebertstrasse 3
81675 München (DE)

(54) CORE AND ASSEMBLY OF A TRANSFORMER, TRANSFORMER AND METHOD OF MANUFACTURING A CORE OF A TRANSFORMER

(57) The present disclosure relates to a core (12) of a transformer (10) which includes at least one leg (14) around which a winding (18) can be wound. The leg (14) includes a first core component (26) made of an amorphous material and a second core component (32) made of electrical steel. The leg (14) extends in a first direction (50) which is perpendicular to the first winding axis (20) and in a second direction (52) which is perpen-

dicular to the first winding axis (20) and to the first direction (50), when the winding (18) is wound around the leg (14). The extension of the leg (14) in the first direction (50) is greater than the extension of the leg (14) in the second direction (52). The leg (14) is tapered in the first direction (50) and/or the second direction (52).

The present disclosure also relates to an assembly, a transformer, and a method of manufacturing a core (12).

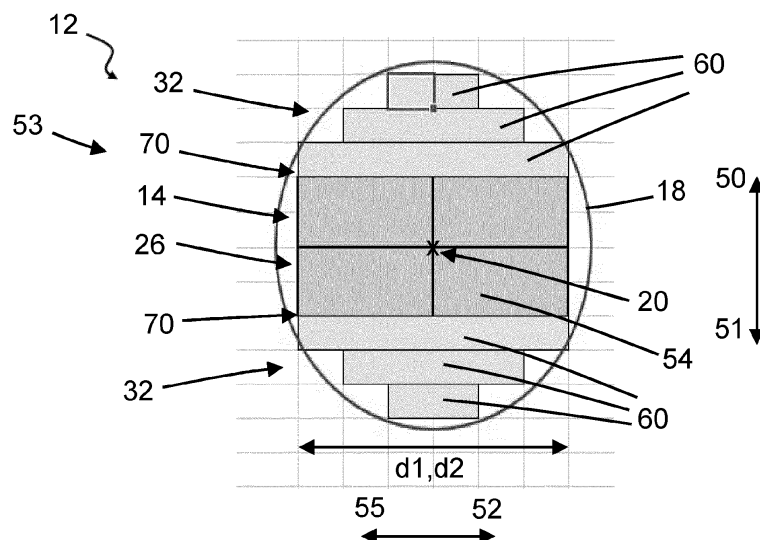


Fig. 3

Description

[0001] Transformers are widely used to convert electricity from a first voltage level to a second voltage level, the second voltage level being either similar, higher or lower than the first voltage level.

[0002] Transformers generally include at least one core and one or more windings wound at least partially around the core. The core(s) can be made of different materials. For instance, transformer cores are often made of electrical steel, sometimes referred to as silicon steel. Alternatively, transformer cores can be made of amorphous steel. Amorphous steel generally may cause lower losses during operation compared to electrical steel. This may allow amorphous steel cores to be more energy efficient than electrical steel cores.

[0003] However, amorphous steel has a relatively low mechanical strength and rigidity, e.g., compared with electrical steel. Moreover, amorphous steel has a relatively high stress sensitivity, e.g., such that losses, e.g., magnetic losses, may fluctuate depending on a degree of stress applied to the core. In particular, the losses may increase with an increasing degree of stress applied to the amorphous steel.

[0004] Transformer cores made of a combination of electrical steel and amorphous steel have been suggested in the prior art, in order to reduce the respective transformer's losses, e.g., compared with a core which is made only of electrical steel, and increase the core's mechanical strength and rigidity, in particular compared with a core which is made only of amorphous steel. This may provide a balance between transformer cores which are made of electrical steel and transformer cores which are made of amorphous steel. Such a core, also referred to as a "hybrid core", is described in WO 2019/123797A1 A1.

[0005] However, several drawbacks remain in the transformer cores, e.g., the hybrid core, known from the prior art. For instance, the application of the hybrid core known from the prior art, in particular as described in WO 2019/123797A1 A1, may be limited, e.g., to transformers with one or more certain power ratings or one or more power rating ranges, and/or the hybrid core known from the prior art may be less advantageous for one or more transformer applications compared with other applications. Moreover, the hybrid core known from the prior art, in particular as described in WO 2019/123797A1 A1, may not be optimized for one or more applications.

[0006] Furthermore, the hybrid core(s) known from the prior art may reduce and/or limit the operation and/or the efficiency and/or the configuration, e.g., shape and/or dimensions, of the windings. For instance, the windings may have to be wound in a certain manner and/or a certain configuration with respect to the hybrid core(s) known from the prior art.

[0007] Moreover, assembling the hybrid core(s) known from the prior art may be relatively complex and/or labor-intensive and/or require a relatively large number of

components.

[0008] The known prior art has not, or at least not sufficiently, addressed one or more of the above-identified issues.

[0009] Thus, the object of the present invention is to provide an improved transformer core, in particular by improving one or more of the above-identified drawbacks.

[0010] The above and other aspects and their implementations are described in greater detail in the drawings, the descriptions, and the claims.

[0011] Various exemplary embodiments of the present disclosure disclosed herein are directed to providing features that will become readily apparent by reference to the following description when taken in conjunction with the accompanying drawings. In accordance with various embodiments, exemplary devices are disclosed herein. It is understood, however, that these embodiments are presented by way of example and not limitation, and it will be apparent to those of ordinary skill in the art who read the present disclosure that various modifications to the disclosed embodiments can be made while remaining within the scope of the present disclosure.

[0012] Thus, the present disclosure is not limited to the exemplary embodiments and applications described and illustrated herein. The above and other aspects and their implementations are described in greater detail in the drawings, the descriptions, and the claims.

[0013] The above-identified object is achieved by a core of a transformer, as defined by the features of claim 1. Preferred embodiments are defined by the features of the dependent claims, respectively.

[0014] Various exemplary embodiments of the present disclosure disclosed herein are directed to providing features that will become readily apparent by reference to the following description when taken in conjunction with the accompanying drawings. In accordance with various embodiments, exemplary devices are disclosed herein. It is understood, however, that these embodiments are presented by way of example and not limitation, and it will be apparent to those of ordinary skill in the art who read the present disclosure that various modifications to the disclosed embodiments can be made while remaining within the scope of the present disclosure.

[0015] Thus, the present disclosure is not limited to the exemplary embodiments and applications described and illustrated herein. Additionally, the specific order and/or hierarchy of steps in the methods disclosed herein are merely exemplary approaches. Based upon design preferences, the specific order or hierarchy of steps of the disclosed methods or processes can be re-arranged while remaining within the scope of the present disclosure. Thus, those of ordinary skill in the art will understand that the methods and techniques disclosed herein present various steps or acts in a sample order, and the present disclosure is not limited to the specific order or hierarchy presented unless expressly stated otherwise.

[0016] The core may be configured such that at least

one winding can be wound at least partially around the core about at least one first winding axis. The winding may be connected or configured to be connected, e.g., via one or more connection elements, to an energy source and a load. The at least one winding may include at least one primary winding connected to the source to draw power from the source and a least one secondary winding connected to the load to deliver energy at a transformed or changed voltage to the load. The winding(s) may also be referred to as coil(s). The at least one winding may be made of an electrically conductive material, such as aluminum and/or copper.

[0017] The core may include a first core component made at least partially of an amorphous material. The core may include at least one leg around which the winding can be at least partially wound about the first winding axis. The leg may include a second core component made at least partially of electrical steel. The first core component and the second core component may be attached, preferably fixedly attached, to each other to provide or form a core composite. The leg may extend in a first direction which may be perpendicular to the first winding axis and in a second direction which may be perpendicular to the first winding axis and to the first direction, when the winding is wound at least partially around the core/leg, i.e., with respect to a state in which the winding is wound at least partially around the core/leg. The extension of the leg in the first direction may be greater than the extension of the leg in the second direction. The extension of the leg in the first direction and the second direction may describe a shape, more specifically one or more dimensions, of the leg in at least one cross-section of the leg which is perpendicular to the first winding axis. In other words, the leg may be elongate, i.e., have a greater dimension in the first direction than in the second direction, in at least one cross-section of the leg which is substantially perpendicular to the first winding axis. The above-defined feature that the extension of the leg in the first direction may be greater than the extension of the leg in the second direction may apply to a plurality of cross-sections of the leg and/or to each cross-section of the leg, along the first winding axis, the cross-sections being perpendicular to the first winding axis.

[0018] In case the core includes a plurality of legs, each leg may include one or more of the at least winding which is/are wound or configured to be wound around the respective leg.

[0019] The first direction and the second direction may lie in a plane which is substantially perpendicular to the first winding axis of the winding, when the winding is wound at least partially around the core/leg, i.e., with respect to a state in which the winding is wound at least partially around the core/leg.

[0020] At least a section of the leg may be tapered in the first direction and/or the second direction. The above-defined feature that at least a section of the leg may be tapered in the first direction and/or the second direction

may apply to at least one cross-section of the leg which is perpendicular to the first winding axis, preferably to a plurality of cross-sections and/or each cross-section of the leg along the first winding axis, the cross-sections being perpendicular to the first winding axis.

[0021] The core may include a plurality of the first core component and/or a plurality of the second core component. In other words, the core composite may include a plurality of first core components and/or a plurality of second core components. The first core components and/or the second core components may be attached to each other to provide or form the core composite. The plurality of first core components and/or the plurality of the second core components may be arranged in a stacked manner, preferably in an alternating manner, preferably in the first direction and/or the second direction. The core may be configured such that the at least one winding may be at least partially wound around a plurality of core components, e.g., one or more first core components and one or more second core components, and/or at least two adjacent first core components and/or at least two adjacent second core components.

[0022] The first core component(s) and the second core component(s) may be arranged symmetrically and/or asymmetrically with respect to at least one symmetry axis. In other words, the leg may be configured symmetrically and/or asymmetrically with respect to at least one symmetry axis.

[0023] As described at the beginning, a hybrid core made of electrical steel and amorphous steel, as described in WO 2019/123797A1 A1, is known from the prior art. However, such a hybrid core is configured specifically for transformers which include windings which are wound around the core in a substantially circular manner. However, one or more types of transformers, in particular relatively small power transformers and/or transformers with a relatively low power rating, in particular in a range from 50 kVA to 10 MVA, may not have and/or require and/or be compatible with windings which are wound in a substantially circular manner. In fact, it is technically impossible to apply the technology described in in WO 2019/123797A1 A1 to other coil/winding shapes, in particular elongate coil/winding shapes.

[0024] Hence, configuring the core such that the leg extends in the first direction to a greater degree or by a greater distance than in the second direction may enable one or more windings to be wound at least partially around the core in a non-circular manner, e.g., in an oval and/or elongate shape. This may allow the core to be used for one or more applications for which the hybrid core(s) known from the prior art is/are not configured to be used and/or the core described may be more suitable and/or more advantageous for one or more applications, compared with the hybrid core(s) known from the prior art.

[0025] In addition, configuring the leg to be tapered in the first direction and/or the second direction may optimize the shape and/or the dimension(s) and/or the vo-

lume of the core with respect to one or more windings to be wound about the core in a non-circular, e.g., oval and/or elongate, manner. This may allow the one or more windings to be wound efficiently about the core, in particular more efficiently than a leg which is not tapered in the first direction and/or the second direction.

[0026] At least a section of the leg may be tapered in the first direction and/or the second direction in a continuous manner and/or in a discontinuous, i.e., stepped, manner, e.g., in or more steps. This tapered configuration of the leg, e.g., in a continuous manner and/or a discontinuous, i.e., stepped, manner, may be achieved in a number of different ways, as described in further detail further below.

[0027] At least a section of the leg may be tapered in the first direction and in a direction which is substantially opposite to the first direction. Alternatively, or additionally, at least a section of the leg may be tapered in the second direction and in a direction which is substantially opposite to the second direction.

[0028] The amorphous material may be a metallic-glass material, such as a nickel-iron or silicon-iron alloy, e.g., Powerlite[®] SA1 manufactured by Metglas[®], Inc.

[0029] The electrical steel may also be referred to as silicon steel. The electrical steel may be regular grain oriented (RGO) silicon steel, in particular cold rolled grain oriented (CRGO) silicon steel.

[0030] The core, more specifically the core composite or the leg, is not limited to the materials described above or herein in general. In fact, the core, more specifically the core composite of the leg, may include one or more further elements and/or one or more further materials.

[0031] The core may include a plurality of the at least one leg around which at least one winding can be at least partially wound about the first winding axis, respectively. Each leg may be configured identically or differently. For instance, at least some of the legs may differ in the configuration(s) and/or the number of the first core component(s) and/or second core component(s).

[0032] The at least one winding can be wound at least partially around the first core component and the second core component, i.e., at least partially around the leg, about the first winding axis.

[0033] The first core component may be toroidally shaped, preferably as an elliptical or oval toroid.

[0034] The first core component may include one or more ribbons or tapes or bands made at least partially of the amorphous material. The one or more ribbons or tapes may be wound at least partially around at least one first core component winding axis, preferably such that the one or more ribbons or tapes are layered, preferably in a direction which is substantially perpendicular to the first core component winding axis. The ribbons or tapes may be wound to form a plurality of loops. In other words, the first core component may be configured as a wound core component, in particular a tape wound core component. This may reduce the manufacturing efforts and/or costs of the first core component, e.g., compared

with a core component composed of stacked (planar) plates. The one or more ribbons or tapes may be wound in a racetrack form and/or elongate form.

[0035] The one or more ribbons or tapes may be wound at least partially around the at least one first core component winding axis such that at least one hollow portion is defined within the first core component. The hollow portion of the first core component may be configured to at least partially receive the at least one winding, when the at least one winding is wound at least partially around the core about the first winding axis. In other words, the at least one winding may extend through the hollow portion of the first core component, when the at least one winding is wound at least partially around the core about the first winding axis. Optionally, the hollow portion of the first core component may be configured to also at least partially receive the second core component.

[0036] The second core component may include a plurality of plates made at least partially of the electrical steel. In other words, the second core component may be laminated, e.g., by stacking the plates. This may also be referred to as a stacked core component. In other words, the second core component may not be configured as a wound core. Each of the plurality of plates may be substantially planar. In other words, the plates may have little to substantially no bend and/or may not be looped. The plurality of plates may be stacked, preferably in a direction which is substantially perpendicular to the first winding axis and/or along the first core component winding axis and/or along in the first direction and/or the second direction.

[0037] Alternatively, the second core component may be configured as a wound core component, in particular a tape wound core component. The second core component may include one or more ribbons or tapes made at least partially of the electrical steel. The one or more ribbons or tapes may be wound at least partially around at least one second core component winding axis, preferably such that the one or more ribbons or tapes are layered, preferably in a direction which is substantially perpendicular to the second core component winding axis.

[0038] Preferably, the one or more ribbons or tapes, e.g., one or more loops of the one or more ribbons or tapes, of the second core component may be arranged at least partially within the hollow portion defined within the first core component. Alternatively, or additionally, the one or more ribbons or tapes, e.g., one or more loops of the one or more ribbons or tapes, of the first core component may be arranged at least partially within a hollow portion defined within the second core component. In other words, the first core component and the second core component may have a nested configuration, i.e., the first core component and the second core component may be at least partially nested within each other.

[0039] The first core component winding axis may coincide with or may extend parallel to the second core component winding axis. The first core component wind-

ing axis and/or the second core component winding axis may coincide with or extend parallel to the first direction. Alternatively, the first core component winding axis and/or the second core component winding axis may coincide with or extend parallel to the second direction.

[0040] Hence, the first core component may be configured as a wound core component, preferably including a plurality of loops, e.g., a plurality of loops of one or more tapes, bands, and/or ribbons. The second core component may be configured as a wound core component, preferably including a plurality of loops, e.g., a plurality of loops of one or more tapes, bands, and/or ribbons. Alternatively, the second core component may be configured as a stacked core component, preferably including a plurality of stacked plates, which are preferably substantially planar.

[0041] Alternatively, the first core component may be configured as a stacked core component, preferably including a plurality of stacked plates, which are preferably substantially planar, and the second core component may be configured as a wound core component or a stacked core component.

[0042] The first core component and the second core component may be adjoined or adjoinable along at least one interface. A dimension of the first core component which extends in a direction along the interface may be substantially identical to a dimension of the second core component which extends in the same direction along the interface. This may provide an improved mechanical stress distribution along at least one surface of the first core component, in particular at least one surface which extends perpendicularly to one or more layers, e.g., one or more layers of ribbon or tape, of the first core component. This may prevent or reduce peak mechanical stresses in the first core component and/or the second core component and/or may provide a more even stress distribution in the first core component and/or the second core component which may reduce the risk of mechanical failure, in particular of the first core component. The first core component and the second core component may be in direct contact along at least a portion of the interface.

[0043] A ratio of the extension of the leg in the first direction to the extension of the leg in the second direction is at least 1.1, preferably at least 1.2, preferably at least 1.4, preferably at least 1.6, preferably at least 1.8, preferably at least 2, preferably at least 2.2, preferably at least 2.4, preferably at least 2.6, preferably at least 2.8, preferably at least 3.

[0044] The first core component may include one or more first ribbons or tapes made at least partially of the amorphous material. The first one or more ribbons or tapes may be wound at least partially around at least one first core component winding axis. The second core component may include one or more second ribbons or tapes made at least partially of the electrical steel. The second one or more ribbons or tapes may be wound at least partially around at least one second core component winding axis. A width of the first ribbons or tapes

may differ from a width of the second ribbons or tapes. The "width", within the context of the present disclosure, is defined as a dimension of the respective ribbon(s) or tape(s) which extends substantially along, e.g., parallel to, the first core component winding axis and/or the second core component winding axis, respectively, and preferably along the first direction and/or the second direction. The width of the first ribbons or tapes may be larger or smaller than the width of the second ribbons or tapes. Varying the width of the first ribbons or tapes and the second ribbons or tapes may allow a shape and/or one or more dimensions of the leg to be adjusted and/or varied, at least more easily and/or more precisely and/or in various and/or different increments. For instance, providing a smaller width of the respective ribbons or tapes may allow the leg to be tapered in at least a section thereof, in particular more easily.

[0045] Alternatively, or additionally, a plurality of first core components may be provided, wherein the ribbons or tapes of at least one of the first core components may have a different width than the ribbons or tapes of a different one of the first core components. Alternatively, or additionally, a plurality of second core components may be provided, wherein the ribbons or tapes of at least one of the second core components may have a different width than the ribbons or tapes of a different one of the second core components.

[0046] The first ribbons or tapes and the second ribbons or tapes and/or the first core component and the second core component may be arranged side-by-side in a direction which extends along the first core component winding axis and/or the second core component winding axis. The first core component winding axis and/or the second core component winding axis may coincide with or extend parallel to the first direction. Such a serial arrangement of the first ribbons or tapes and the second ribbons or tapes and/or the first core component and the second core component along the first core component winding axis and/or the second core component winding axis may allow a dimension of the leg along the first core component winding axis and/or the second core component winding axis to be varied, e.g., increased when needed/desired, and/or to vary a shape of the leg, in particular in at least one cross-section of the leg, in particular in at least one cross-section of the leg which is perpendicular to the first winding axis. For instance, this may allow the leg to have a dimension in the first direction, which may coincide with or is parallel with the first core component winding axis and/or the second core component winding axis, which is greater than a dimension of the leg in the second direction.

[0047] Preferably, the first core component winding axis and/or the second core component winding axis may coincide with or extend parallel to the first direction and the extension of the leg in the first direction may be greater than the extension of the leg in the second direction.

[0048] Alternatively, or additionally, the first ribbons

ortapes and the second ribbons or tapes and/or the first core component and the second core component may be arranged side-by-side in a direction which is substantially perpendicular to the first core component winding axis and/or the second core component winding axis. The first core component may be arranged at least partially within a hollow space defined at least partially within the second core component. Alternatively, or additionally, the second core component may be arranged at least partially within a hollow space defined at least partially within the first core component.

[0049] Such an arrangement of the first ribbons or tapes and the second ribbons or tapes and/or the first core component and the second core component side-by-side in a direction which is substantially perpendicular to the first core component winding axis and/or the second core component winding axis may allow a dimension of the leg perpendicular to the first core component winding axis and/or the second core component winding axis to be varied, e.g., increased when needed/desired, and/or to vary a shape of the leg, in particular in at least one cross-section of the leg, in particular in at least one cross-section of the leg which is perpendicular to the first winding axis.

[0050] A dimension of the first core component which extends in a direction which extends along the first core component winding axis and/or the second core component winding axis and/or a dimension of the first core component which extends in a direction which is substantially perpendicular to the first core component winding axis and/or the second core component winding axis may differ from a dimension of the second core component which extends in the same direction. This may allow, e.g., one or more dimension(s) and/or shape of the leg to be varied, in particularly more easily. For instance, by choosing the dimension of the first core component and/or the second core component specified above accordingly, the increment(s) by which the shape and/or dimension(s) of the leg is/are adjusted may be adapted and/or chosen and/or individualized accordingly.

[0051] The first core component may include a plurality of first layers and the second core component may include a plurality of second layers. The first layers may be stacked along a direction which is substantially perpendicular to a direction in which the second layers are stacked.

[0052] The first core component may include a plurality of first layers and the second core component may include a plurality of second layers. The first layers and the second layers may be stacked in the same direction.

[0053] The core may be configured for use in a transformer with a power rating in a range of 50 kVA to 10 MVA. As discussed in the beginning, the application of the hybrid core known from the prior art, in particular as described in WO 2019/123797A1 A1, may be limited, e.g., to transformers with one or more certain power ratings or one or more power rating ranges, in particular to relatively high power ratings. However, the core de-

scribed herein is not limited to such specific applications and may be employed for lower ratings, e.g., in a range of 50 kVA to 10 MVA.

[0054] The core may further include at least one clamping device which clamps or is configured to clamp the second core component. The clamping device may be configured to clamp or fixedly interconnect, i.e., hold together, one or more individual elements, e.g., individual plates, of the second core component.

[0055] The clamping device may be at least partially arranged between the first core component and the second core component.

[0056] The first core component may be free of a casing, in particular a casing which only at least partially encompasses the first core component. This may allow the core to be configured, e.g., adapted, more flexibly, in particular since the first core component may be free of a casing which may constrain the dimensions and/or the shape of the core, in particular the first core component. This may also simplify the construction and/or the assembly process of the core. The core may include at least one clamping device which clamps the first core component and the second core component together. Such a clamping device is not to be understood as a "casing" within the present context.

[0057] The core composite and/or the leg may have a stepped configuration along at least a section of a contour of the core composite and/or the leg.

[0058] The core composite and/or the leg may be tapered in at least a section thereof in the first direction and/or the second direction in one or more steps and/or in a stepped manner.

[0059] The first core component and the second core component may be in direct contact with each other along at least a section of an interface between the first core component and the second core component.

[0060] The first core component and the second core component may be adjoined or adjoinable along at least one interface. The interface may be free of non-magnetic material and/or resin and/or wood. This may simplify the construction and/or the assembly process of the core. In many applications, transformer cores include one or more additive materials, such as non-magnetic material and/or resin and/or wood, e.g., for rigidity and/or insulating purposes. The core described herein is configured such that such additive materials between the first core component and the second core component can be omitted. Preferably, the first core component and the second core component are in direct contact along the interface.

[0061] The present disclosure also relates to an assembly of a transformer. The same features, configurations, and advantages, as described above with respect to the core, apply to the assembly accordingly.

[0062] The assembly may include a core, in particular the core according to any of the embodiments described herein. The assembly may include at least one winding which is wound or configured to be wound at least par-

tially around the core, more specifically the leg of the core.

[0063] The winding may extend in a first winding direction, which is perpendicular to a winding axis of the winding, and in a second winding direction, which is perpendicular to a winding axis of the winding and to the first direction. The extension of the winding in the first winding direction may be greater than the extension of the winding in the second winding direction. A ratio of the first winding direction to the second winding direction may be at least 1.1, preferably at least 1.2, preferably at least 1.4, preferably at least 1.6, preferably at least 1.8, preferably at least 2, preferably at least 2.2, preferably at least 2.4, preferably at least 2.6, preferably at least 2.8, preferably at least 3.

[0064] The present disclosure also relates to a transformer. The same features, configurations, and advantages, as described above with respect to the core, apply to the transformer accordingly.

[0065] The transformer may include the assembly according to any of the embodiments described herein. The transformer may include one or more terminals for connecting one or more cables to the transformer. The transformer may have any number of legs, e.g., 1, 2, 3, 4, 5, or more legs. One or more of the legs may include a plurality of first core components and/or a plurality of second core components.

[0066] The present disclosure also relates to a method of manufacturing a core of a transformer, preferably a method of manufacturing the core according to any of the embodiments described herein. The same features, configurations, and advantages, as described above with respect to the core, apply to the method accordingly.

[0067] The core may include at least one leg and may be configured such that at least one winding can be wound at least partially around the leg about at least one first winding axis.

[0068] The method may include providing a first core component made at least partially of at least one amorphous material. The method may include providing at least one second core component made at least partially of electrical steel. The method may include attaching the first core component to the second core component to provide a core composite of the leg. In other words, the leg may be made of the core composite which includes the first core component and the second core component. The leg may extend in a first direction which is perpendicular to the first winding axis and in a second direction which is perpendicular to the first winding axis and to the first direction, when the winding is wound at least partially around the leg. The extension of the leg in the first direction may be greater than the extension of the leg in the second direction. At least a section of the leg may be tapered in the first direction and/or the second direction.

[0069] The following list of aspects provides alternative and/or further features of the invention:

1. A core of a transformer, wherein the core is configured such that at least one winding can be wound at least partially around the core about at least one first winding axis, wherein the core includes:

at least one leg around which the winding can be at least partially wound about the first winding axis;

wherein the leg includes a first core component made at least partially of a first material, preferably an amorphous material and a second core component made at least partially of a second material which is different than the first material, preferably wherein the second core component is made at least partially of electrical steel;

preferably wherein the first core component and the second core component are attached to each other to provide a core composite of the leg;

wherein:

the leg extends in a first direction which is perpendicular to the first winding axis and in a second direction which is perpendicular to the first winding axis and to the first direction, when the winding is wound at least partially around the leg, wherein the extension of the leg in the first direction is greater than the extension of the leg in the second direction; and/or

at least a section of the leg is tapered in the first direction and/or the second direction.

2. The core according to aspect 1, wherein the first core component includes one or more ribbons or tapes made at least partially of the amorphous material, wherein the one or more ribbons or tapes are wound at least partially around at least one first core component winding axis, preferably such that the one or more ribbons or tapes are layered, preferably in a direction which is substantially perpendicular to the first core component winding axis.

3. The core according to any of the preceding aspects, wherein the second core component includes a plurality of plates made at least partially of the electrical steel, wherein the plurality of plates are stacked, preferably in a direction which is substantially perpendicular to the first winding axis and/or along the first core component winding axis, preferably wherein each of the plurality of plates is substantially planar.

4. The core according to any of the preceding aspects, wherein the first core component and the second core component are adjoined or adjoinable along at least one interface, wherein a dimension of

the first core component which extends in a direction along the interface is substantially identical to a dimension of the second core component which extends in the same direction along the interface.

5. The core according to any of the preceding aspects, wherein the second core component includes one or more ribbons or tapes made at least partially of the electrical steel, wherein the one or more ribbons or tapes are wound at least partially around at least one second core component winding axis, preferably such that the one or more ribbons or tapes are layered, preferably in a direction which is substantially perpendicular to the second core component winding axis.

6. The core according to any of the preceding aspects, wherein a ratio of the extension of the leg in the first direction to the extension of the leg in the second direction is at least 1.1, preferably at least 1.2, preferably at least 1.4, preferably at least 1.6, preferably at least 1.8, preferably at least 2, preferably at least 2.2, preferably at least 2.4, preferably at least 2.6, preferably at least 2.8, preferably at least 3.

7. The core according to any of the preceding aspects, wherein the first core component includes one or more first ribbons or tapes made at least partially of the amorphous material, wherein the first one or more ribbons or tapes are wound at least partially around at least one first core component winding axis, wherein the second core component includes one or more second ribbons or tapes made at least partially of the electrical steel, wherein the second one or more ribbons or tapes are wound at least partially around at least one second core component winding axis, and wherein a width of the first ribbons or tapes differs from a width of the second ribbons or tapes.

8. The core according to aspect 7, wherein the first ribbons or tapes and the second ribbons or tapes and/or the first core component and the second core component are arranged side-by-side:

in a direction which extends along the first core component winding axis and/or the second core component winding axis;
and/or
in a direction which is substantially perpendicular to the first core component winding axis and/or the second core component winding axis.

9. The core according to aspect 7 or 8, wherein a dimension of the first core component which extends in a direction which extends along the first core component winding axis and/or the second core

component winding axis and/or a dimension of the first core component which extends in a direction which is substantially perpendicular to the first core component winding axis and/or the second core component winding axis differs from a dimension of the second core component which extends in the same direction.

10. The core according to any of the preceding aspects, wherein the first core component includes a plurality of first layers and the second core component includes a plurality of second layers, wherein the first layers are stacked along a direction which is substantially perpendicular to a direction in which the second layers are stacked.

11. The core according to any of the preceding aspects, wherein the first core component includes a plurality of first layers and the second core component includes a plurality of second layers, wherein the first layers and the second layers are stacked in the same direction.

12. The core according to any of the preceding aspects, wherein the core is configured for use in a transformer with a power rating in a range of 50 kVA to 10 MVA.

13. The core according to any of the preceding aspects, further including at least one clamping device which clamps or is configured to clamp the second core component.

14. The core according to aspect 13, wherein the clamping device is at least partially arranged between the first core component and the second core component.

15. The core according to any of the preceding aspects, wherein the first core component is free of a casing.

16. The core according to any of the preceding aspects, wherein the leg and/or the core composite has a stepped configuration along at least a section of a contour of the core.

17. The core according to any of the preceding aspects, wherein the leg and/or the core composite is tapered in at least a section thereof in the first direction and/or the second direction in one or more steps and/or in a stepped manner.

18. The core according to any of the preceding aspects, wherein the first core component and the second core component are in direct contact with each other along at least a section of an interface between the first core component and the second

core component.

19. The core according to any of the preceding aspects, wherein the first core component and the second core component are adjoined or adjoinable along at least one interface, wherein the interface is free of non-magnetic material and/or resin and/or wood.

20. An assembly of a transformer, the assembly including the core according to any of the preceding aspects and at least one winding which is wound or configured to be wound at least partially around the core.

21. The assembly according aspect 20, wherein the winding extends in a first winding direction, which is perpendicular to a winding axis of the winding, and in a second winding direction, which is perpendicular to a winding axis of the winding and to the first direction, wherein the extension of the winding in the first winding direction is greater than the extension of the winding in the second winding direction, preferably wherein a ratio of the extension of the winding in the first winding direction to the extension of the winding in the second winding direction is at least 1.1, preferably at least 1.2, preferably at least 1.4, preferably at least 1.6, preferably at least 1.8, preferably at least 2, preferably at least 2.2, preferably at least 2.4, preferably at least 2.6, preferably at least 2.8, preferably at least 3.

22. A transformer which includes the assembly according to aspect 20 or 21 and one or more terminals for connecting one or more cables to the transformer.

23. A method of manufacturing a core of a transformer, preferably the core according to any of aspects 1 to 19, wherein the core includes at least one leg and is configured such that at least one winding can be wound at least partially around the leg about at least one first winding axis, wherein the method includes:

providing a first core component made at least partially of a first material, preferably an amorphous material; and
providing at least one second core component made at least partially of a second material which is different than the first material, preferably wherein the second core component is made at least partially of electrical steel;
optionally, attaching the first core component to the second core component to provide a core composite of the leg;
wherein:

the leg extends in a first direction which is perpendicular to the first winding axis and in

a second direction which is perpendicular to the first winding axis and to the first direction, when the winding is wound at least partially around the leg, wherein the extension of the leg in the first direction is greater than the extension of the leg in the second direction;

and/or

at least a section of the leg is tapered in the first direction and/or the second direction.

[0070] Embodiments of the present invention are further elucidated below with reference to the figures. The figures are schematic drawings and as such may not show all details of the systems and their components. Particularly, the drawings are not necessarily to scale and the shown dimensions are only exemplary and may vary. The drawings illustrate exemplary embodiments to provide a thorough understanding of the present invention. The drawings are not intended to limit the scope of the invention, which is defined by the appended claims and is to include the equivalents thereof.

Fig. 1 shows, in a schematic perspective view, a transformer according to an embodiment of the present disclosure;

Fig. 2 shows, in a schematic perspective view, the transformer of Fig. 1 according to a modified embodiment of the present disclosure;

Fig. 3 shows, in a schematic cross-sectional view, a core of a transformer according to an embodiment of the present disclosure;

Fig. 4A shows, in a perspective side view, a core of a transformer according to an embodiment of the present disclosure;

Fig. 4B shows a cross-sectional view of the core of Fig. 4A;

Fig. 5A shows, in a perspective side view, a core of a transformer according to an embodiment of the present disclosure;

Fig. 5B shows a cross-sectional view of the core of Fig. 5A;

Fig. 6A shows, in a perspective side view, a core of a transformer according to an embodiment of the present disclosure;

Fig. 6B shows a cross-sectional view of the core of Fig. 6A;

Fig. 7A shows, in a perspective side view, a core of a transformer according to an embodiment of the present disclosure;

Fig. 7B shows a cross-sectional view of the core of Fig. 7A;

Fig. 8A shows, in a perspective side view, a core of a transformer according to an embodiment of the present disclosure;

Fig. 8B shows a cross-sectional view of the core of Fig. 8A;

Fig. 9A shows, in a perspective side view, a core of

- a transformer according to an embodiment of the present disclosure;
- Fig. 9B shows a cross-sectional view of the core of Fig. 9A;
- Fig. 10A shows, in a perspective side view, a core of a transformer according to an embodiment of the present disclosure;
- Fig. 10B shows a cross-sectional view of the core of Fig. 10A;
- Fig. 11A shows, in a perspective side view, a core of a transformer according to an embodiment of the present disclosure;
- Fig. 11B shows a cross-sectional view of the core of Fig. 11A.

[0071] Fig. 1 shows, in a schematic perspective view, a transformer 10 which may include at least one core 12. The core 12 may include one or more legs 14, sometimes also referred to as phases or limbs. As an example, the core 12 of Fig. 1 has three legs 14. However, the core 12 may include more or less legs than shown in the Figures. The transformer 10 may include one or more windings 18, which are shown schematically in Fig. 1. The one or more windings 18 may be wound at least partially around each leg 14 about at least one first winding axis 20. For the sake of clarity, only one of the winding axes 20 is indicated with a reference sign in Fig. 1. The transformer 10 may include one or more connection elements 24 to electrically connect the one or more windings 18 to one or more components, e.g., to an energy source and/or a load. For instance, the one or more windings 18 may include at least one primary winding connectable, e.g., via the one or more connection elements 24, to a source to draw power from the source and a least one secondary winding connectable, e.g., via the one or more connection elements 24, to a load to deliver energy at a transformed or changed voltage to the load. The winding(s) 18 may also be referred to as coil(s). The winding(s) 18 may be made of an electrically conductive material, such as aluminum and/or copper.

[0072] The leg 14 may include a first core component 26 made at least partially of an amorphous material and a second core component 32 made at least partially of electrical steel. The first core component 26 and the second core component 32 may be attached to each other to provide or form a core composite 36. In particular, the transformer 10 may include at least one first clamping device 42 (see Fig. 2) which is configured to clamp the first core component 26 and the second core component 32 together, e.g., to fixedly connect the first core component 26 and the second core component 32.

[0073] The transformer 10 may include at least one second clamping device 44 configured to clamp the first core component 26 or the second core component 32, preferably substantially separately or independently from each other. For instance, the second clamping device 44 may be configured to fixedly interconnect, i.e., hold together, one or more individual elements, e.g., individual

plates and/or ribbons and/or tapes, of the first core component 26 or the second core component 32.

[0074] The first clamping device 42 may at least partially encompass and/or receive the second clamping device 44.

[0075] Figs. 3 to 11 show various configurations of the core 12. In particular, the leg 14, preferably each leg 14, may extend in a first direction 50 which is perpendicular to the first winding axis 20. The leg 14, preferably each leg 14, may extend in a second direction 52 which is perpendicular to the first winding axis 20 and to the first direction 50, when the winding 18 is wound at least partially around the respective leg 14. The extension of the respective leg 14 in the first direction 50 may be greater than the extension of the respective leg 14 in the first direction 52. In other words, the leg 14 may extend in the first direction 50 to a greater degree or by a greater distance than in the second direction 52. The winding(s) 18 is/are shown only schematically in Fig. 3. Based on the perspective of Fig. 3, the first winding axis 20 extends into the drawing plane of Fig. 3. The grid shown in the background of Fig. 3 is not a part of the core 12 but is instead provided as an exemplary scale.

[0076] The leg 14 may be tapered in at least a section thereof in the first direction 50 and/or the second direction 52. At least a section of the leg 14 may be tapered in the first direction 50 and in a direction 51 which is substantially opposite to the first direction 50. Alternatively, or additionally, at least a section of the leg 14 may be tapered in the second direction 52 and in a direction 55 which is substantially opposite to the second direction 52.

[0077] The core 12 and the winding(s) 18 which is/are wound or configured to be wound at least partially around the leg 14 of the core 12 may also be referred to herein as an assembly 53.

[0078] As shown in Figs. 3 and 4, the first core component 26 may include one or more ribbons or tapes 54 made at least partially of the amorphous material. The one or more ribbons or tapes 54 may be wound at least partially around at least one first core component winding axis 56 (see Fig. 4), preferably such that the one or more ribbons or tapes 54 are layered, preferably in a direction which is substantially perpendicular to the first core component winding axis 56.

[0079] As shown in Fig. 3, the second core component 32 may include a plurality of plates 60 made at least partially of the electrical steel. The plurality of plates 60 are stacked, preferably in a direction which is substantially perpendicular to the first winding axis 20 and/or along the first core component winding axis 56. Each of the plurality of plates 60 may be substantially planar.

[0080] Alternatively, or additionally, the second core component 32 may include one or more ribbons or tapes 64 made at least partially of the electrical steel, as shown in Fig. 4. The one or more ribbons or tapes 64 may be wound at least partially around at least one second core component winding axis 66, preferably such that the one or more ribbons or tapes 64 are layered, preferably in a

direction which is substantially perpendicular to the second core component winding axis 66. As shown in Fig. 4, the first core component winding axis 56 and the second core component winding axis 66 may coincide. However, this is only an example. For instance, the first core component winding axis 56 and the second core component winding axis 66 may not coincide. The first core component winding axis 56 and the second core component winding axis 66 may be parallel or perpendicular to each other.

[0081] The first core component 26 and the second core component 32 may be adjoined or adjoinable along at least one interface 70. A dimension d1 of the first core component 26 which extends in a direction along the interface 70 is substantially identical to a dimension d2 of the second core component 32 which extends in the same direction along the interface 70, as shown in in Fig. 3 in an exemplary manner.

[0082] As shown in the Figures, the first ribbons or tapes 54 and the second ribbons or tapes 64 and/or the first core component 26 and the second core component 32 may be arranged side-by-side in a direction 74 which is substantially perpendicular to the first core component winding axis 56 and/or the second core component winding axis 66.

[0083] Alternatively, the first ribbons or tapes 54 and the second ribbons or tapes 64 and/or the first core component 26 and the second core component 32 may be arranged side-by-side in a direction 78 which extends along the first core component winding axis 65 and/or the second core component winding axis 66, as shown, e.g., in Figs. 5, 8, 9, and 11. A combination of these embodiments, in particular with respect to the relative arrangement of the first ribbons or tapes 54 and the second ribbons or tapes 64 and/or the first core component 26 and the second core component 32, is also possible, as shown, e.g., in Figs. 5, 9, and 11.

[0084] The first core component 26 may include one or more first ribbons or tapes 54 made at least partially of the amorphous material. The first one or more ribbons or tapes 54 may be wound at least partially around at least one first core component winding axis 56. The second core component 32 may include one or more second ribbons or tapes 64 made at least partially of the electrical steel. The second one or more ribbons or tapes 64 may be wound at least partially around at least one second core component winding axis 66. A width w1 of the first ribbons or tapes 54 may differ from a width w2 of the second ribbons or tapes 64, as shown in as an example in Fig. 4. The "width", within the context of the present disclosure, is defined as a dimension of the respective ribbons or tapes 54, 64 which extends substantially along, e.g., parallel to, the first core component winding axis 56 and/or the second core component winding axis 66, and preferably along the first direction 50 and/or the second direction 52. The width w1 of the first ribbons or tapes 54 may be larger or smaller than the width w2 of the second ribbons or tapes 64.

Claims

1. A core (12) of a transformer (10), wherein the core (12) is configured such that at least one winding (18) can be wound at least partially around the core (12) about at least one first winding axis (20), wherein the core (12) includes:
 - at least one leg (14) around which the winding (18) can be at least partially wound about the first winding axis (20);
 - wherein the leg (14) includes a first core component (26) made at least partially of an amorphous material and a second core component (32) made at least partially of electrical steel;
 - wherein the first core component (26) and the second core component (32) are attached to each other to provide a core composite (36);
 - wherein the leg (14) extends in a first direction (50) which is perpendicular to the first winding axis (20) and in a second direction (52) which is perpendicular to the first winding axis (20) and to the first direction (50), when the winding (18) is wound at least partially around the leg (14), wherein the extension of the leg (14) in the first direction (50) is greater than the extension of the leg (14) in the second direction (52); and
 - wherein at least a section of the leg (14) is tapered in the first direction (50) and/or the second direction (52).
2. The core (12) according to claim 1, wherein the first core component (26) includes one or more ribbons or tapes (54) made at least partially of the amorphous material, wherein the one or more ribbons or tapes (54) are wound at least partially around at least one first core component winding axis (56), preferably such that the one or more ribbons or tapes (54) are layered, preferably in a direction which is substantially perpendicular to the first core component winding axis (56).
3. The core (12) according to any of the preceding claims, wherein the second core component (32) includes a plurality of plates (60) made at least partially of the electrical steel, wherein the plurality of plates (60) are stacked, preferably in a direction which is substantially perpendicular to the first winding axis (20) and/or along the first core component winding axis (56), preferably wherein each of the plurality of plates (60) is substantially planar.
4. The core (12) according to any of the preceding claims, wherein the first core component (26) and the second core component (32) are adjoined or adjoinable along at least one interface (70), wherein a dimension (d1) of the first core component (26) which extends in a direction along the interface (70)

is substantially identical to a dimension (d2) of the second core component (32) which extends in the same direction along the interface (70).

5. The core (12) according to any of the preceding claims, wherein the second core component (32) includes one or more ribbons or tapes (64) made at least partially of the electrical steel, wherein the one or more ribbons or tapes (64) are wound at least partially around at least one second core component winding axis (66), preferably such that the one or more ribbons or tapes (64) are layered, preferably in a direction which is substantially perpendicular to the second core component winding axis (66). 5 10
6. The core (12) according to any of the preceding claims, wherein a ratio of the extension of the leg (14) in the first direction to the extension of the leg (14) in the second direction is at least 1.1, preferably at least 1.2, preferably at least 1.4, preferably at least 1.6, preferably at least 1.8, preferably at least 2, preferably at least 2.2, preferably at least 2.4, preferably at least 2.6, preferably at least 2.8, preferably at least 3. 15 20
7. The core (12) according to any of the preceding claims, wherein the first core component (26) includes one or more first ribbons or tapes (54) made at least partially of the amorphous material, wherein the first one or more ribbons or tapes (54) are wound at least partially around at least one first core component winding axis (56), wherein the second core component (32) includes one or more second ribbons or tapes (64) made at least partially of the electrical steel, wherein the second one or more ribbons or tapes (64) are wound at least partially around at least one second core component winding axis (66), and wherein a width (w1) of the first ribbons or tapes (54) differs from a width (w2) of the second ribbons or tapes (64). 25 30 35 40
8. The core (12) according to claim 7, wherein the first ribbons or tapes (54) and the second ribbons or tapes (64) and/or the first core component (26) and the second core component (32) are arranged side-by-side: 45
 - in a direction (78) which extends along the first core component winding axis (65) and/or the second core component winding axis (66); 50
 - and/or
 - in a direction (74) which is substantially perpendicular to the first core component winding axis (56) and/or the second core component winding axis (66). 55
9. The core (12) according to any of the preceding claims, wherein the core (12) is configured for use

in a transformer (10) with a power rating in a range of 50 kVA to 10 MVA.

10. The core (12) according to any of the preceding claims, further including at least one clamping device (44) which clamps or is configured to clamp the second core component (32), preferably wherein the clamping device (44) is at least partially arranged between the first core component (26) and the second core component (32).
11. The core (12) according to any of the preceding claims, wherein the first core component (26) is free of a casing, preferably wherein the first core component (26) and the second core component (32) are in direct contact with each other along at least a section of an interface (70) between the first core component (26) and the second core component (32).
12. The core (12) according to any of the preceding claims, wherein the first core component (26) and the second core component (32) are adjoined or adjoinable along at least one interface (70), wherein the interface (70) is free of non-magnetic material and/or resin and/or wood. 25
13. An assembly (53) of a transformer (10), the assembly (53) including the core (12) according to any of the preceding claims and at least one winding (18) which is wound or configured to be wound at least partially around the leg (14) of the core (12). 30
14. A transformer (10) which includes the assembly (53) according to claim 13 and one or more terminals (24) for connecting one or more cables to the transformer (10). 35
15. A method of manufacturing a core (12) of a transformer (10), preferably the core (12) according to any of claims 1 to 12, wherein the core (12) includes at least one leg (14) and is configured such that at least one winding (18) can be wound at least partially around the leg (14) about at least one first winding axis (20), wherein the method includes: 40 45
 - providing a first core component (26) made at least partially of at least one amorphous material; and
 - providing at least one second core component (32) made at least partially of electrical steel; attaching the first core component (26) to the second core component (32) to provide a core composite (36) of the leg (14); wherein the leg (14) extends in a first direction (50) which is perpendicular to the first winding axis (20) and in a second direction (52) which is perpendicular to the first winding axis (20) and to the first direction (50), when the winding (18) is

wound at least partially around the leg (14), wherein the extension of the leg (14) in the first direction (50) is greater than the extension of the leg (14) in the second direction (52); and wherein the leg (14) is tapered in the first direction (50) and/or the second direction (52).

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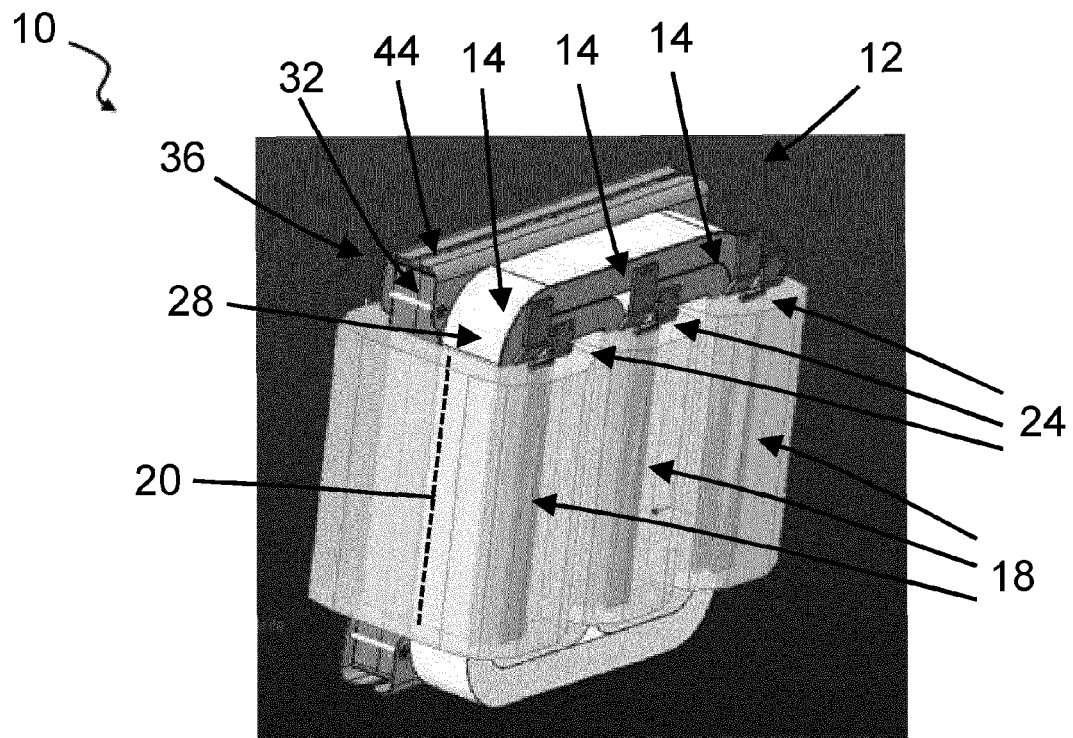


Fig. 1

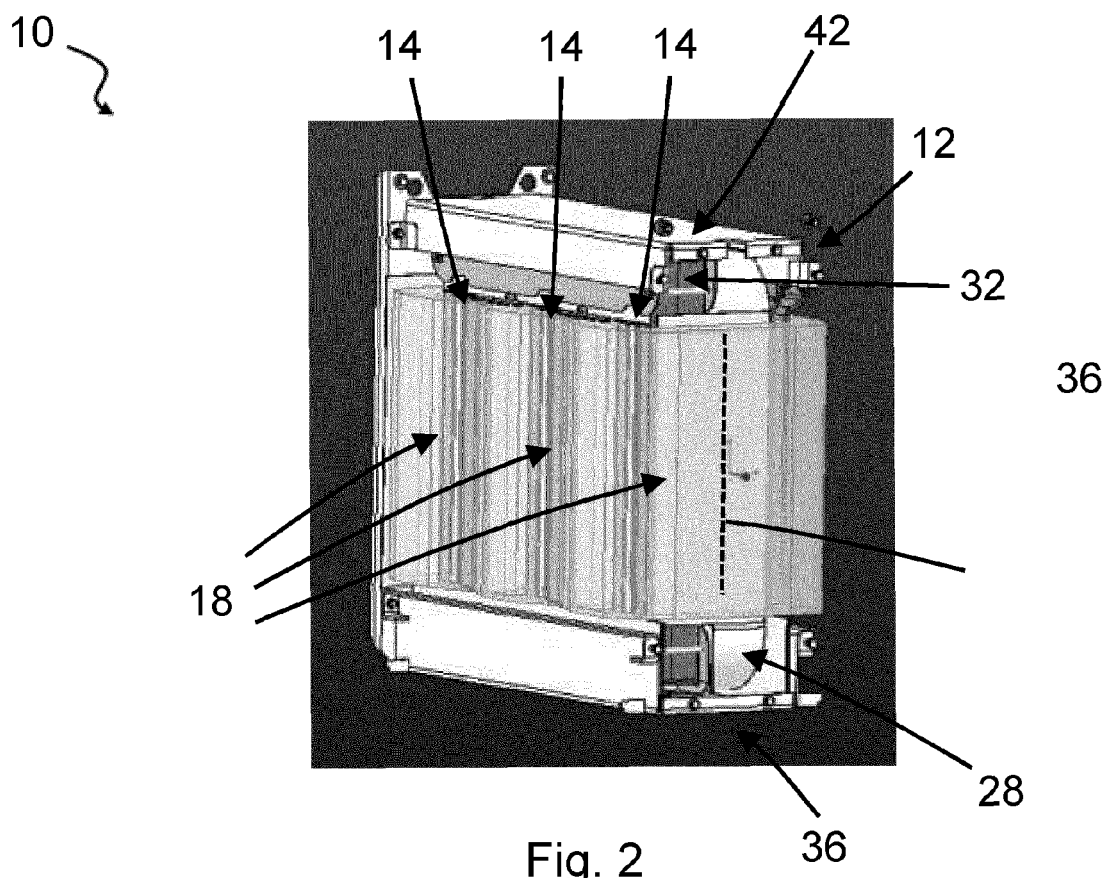


Fig. 2

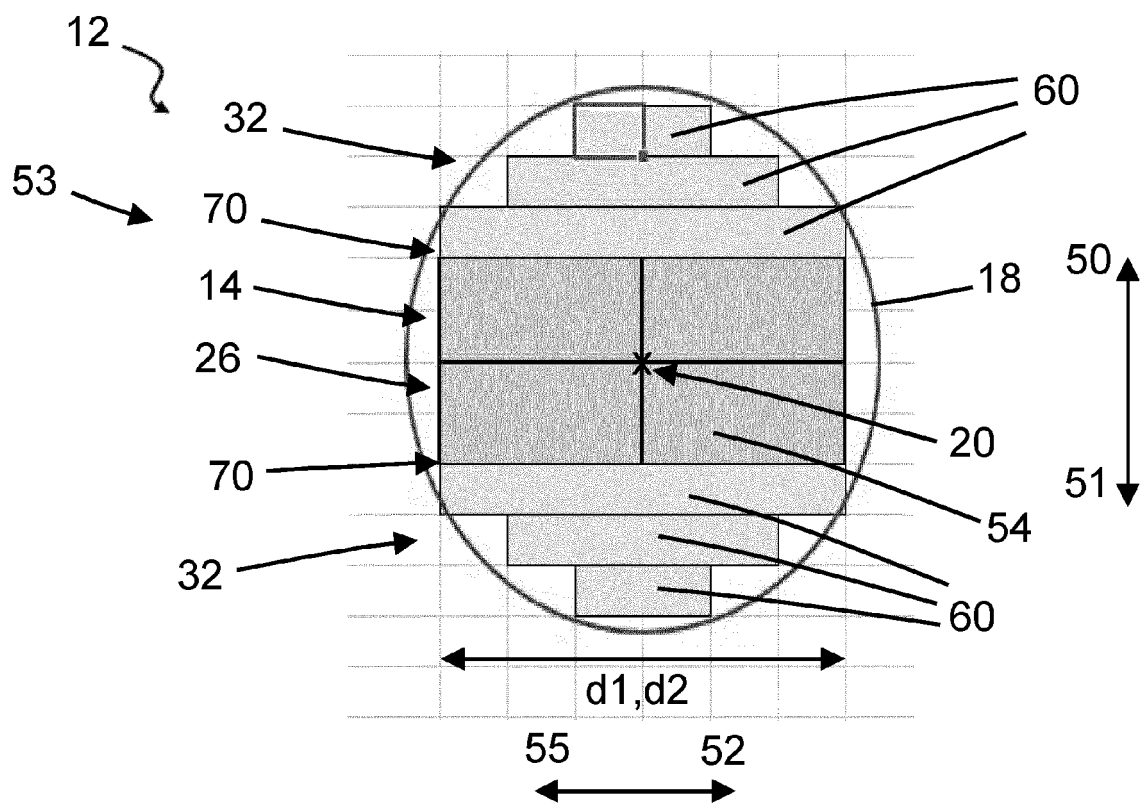


Fig. 3

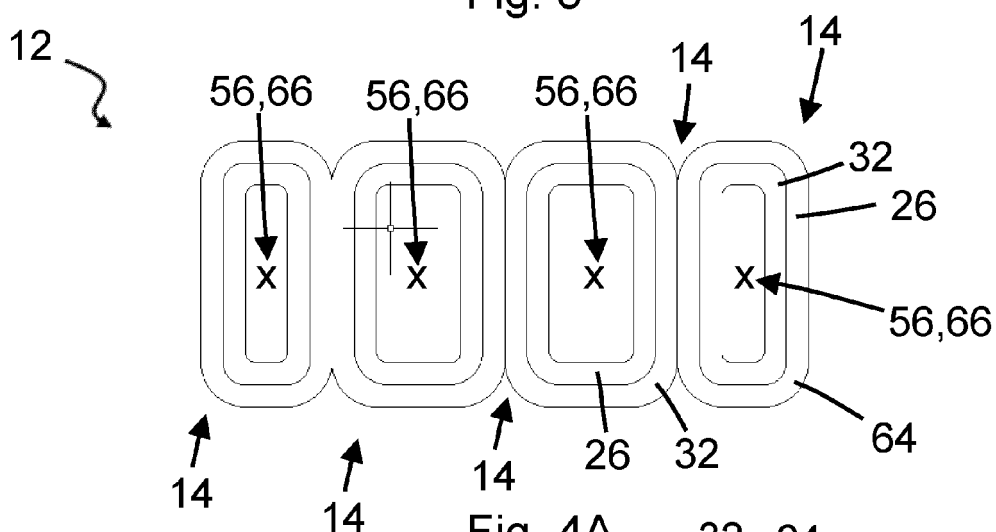


Fig. 4A

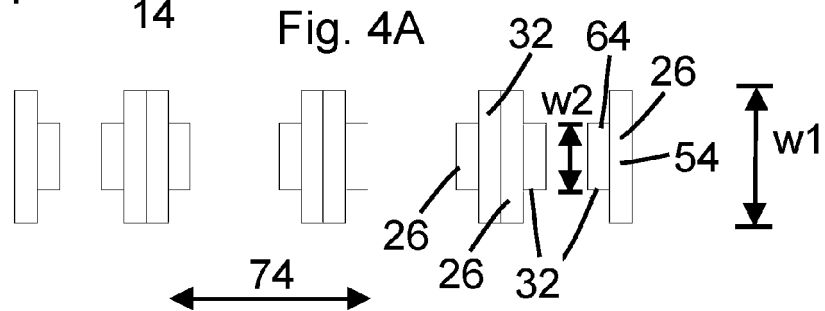
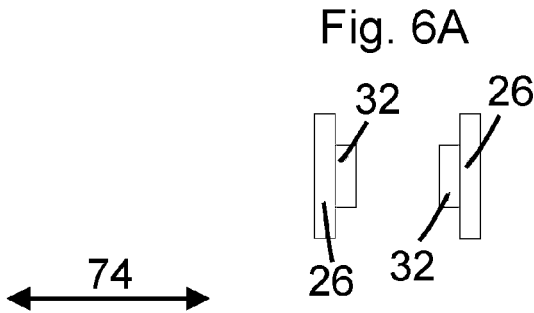
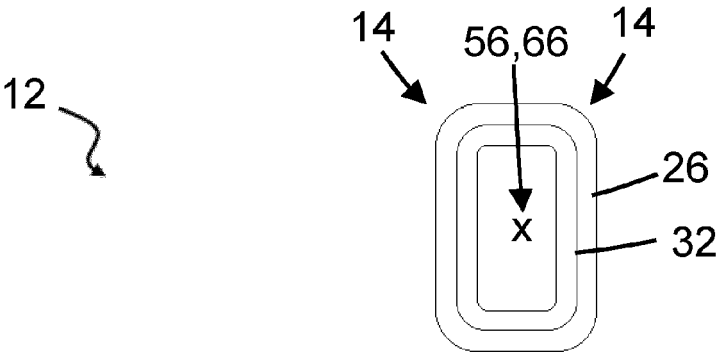
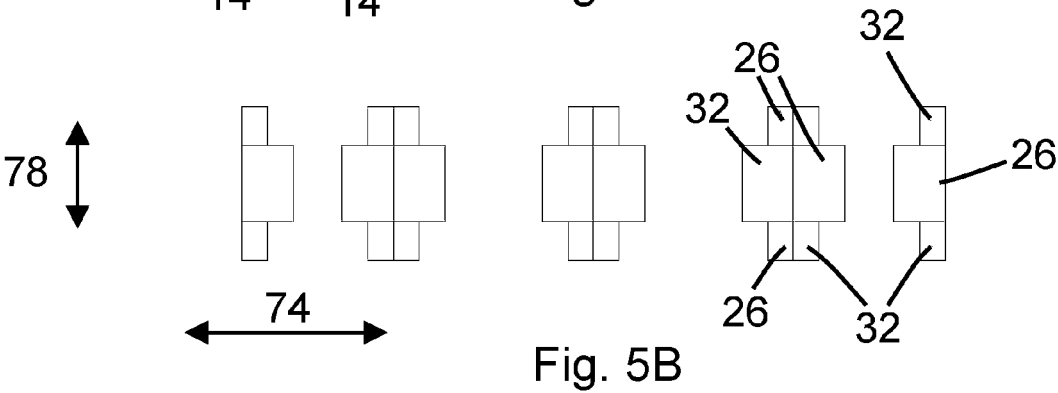
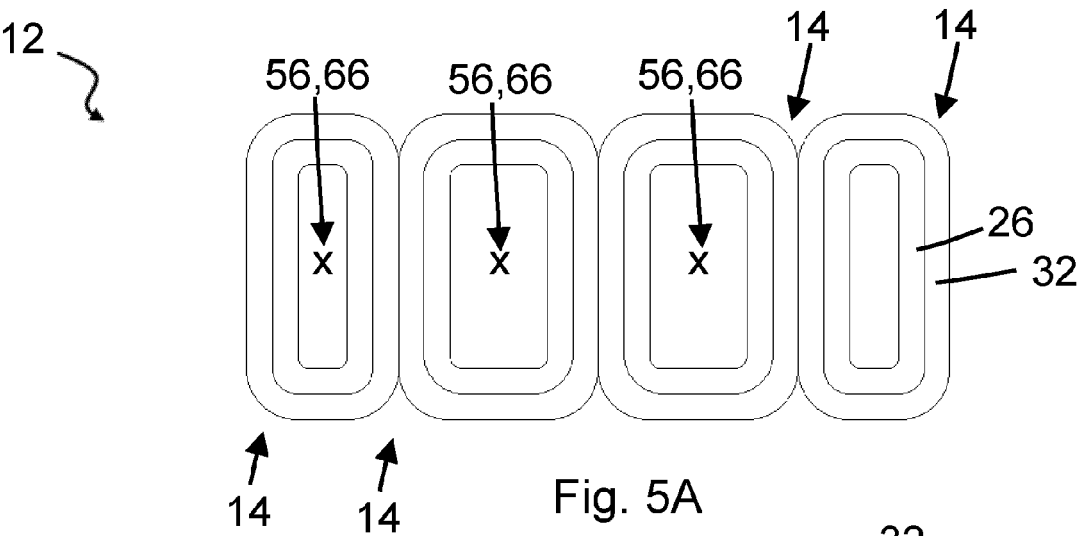


Fig. 4B



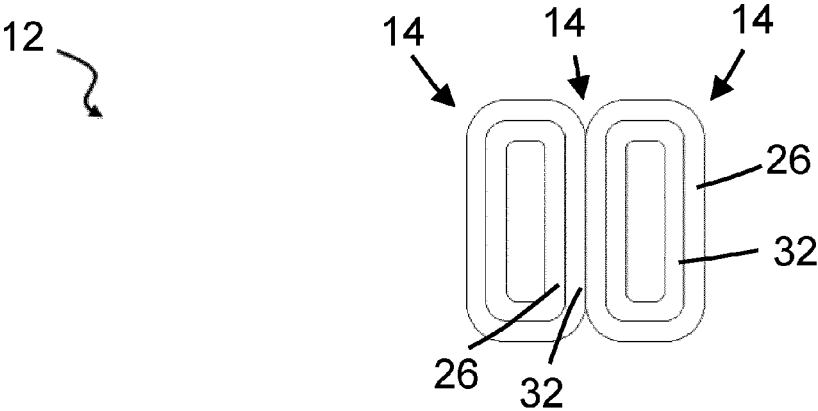


Fig. 7A

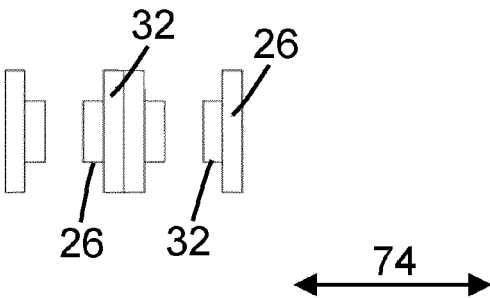


Fig. 7B

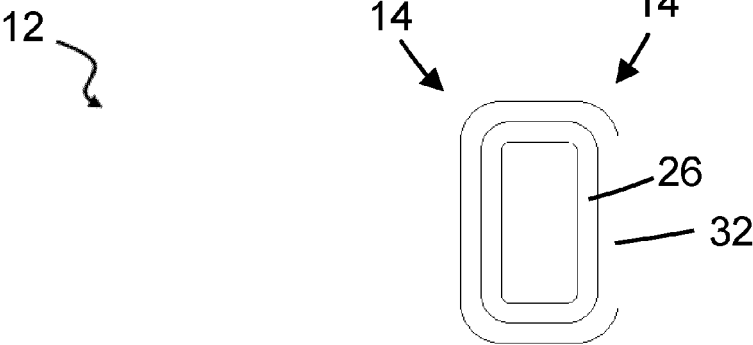


Fig. 8A

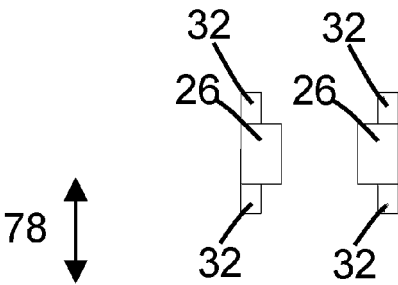


Fig. 8B

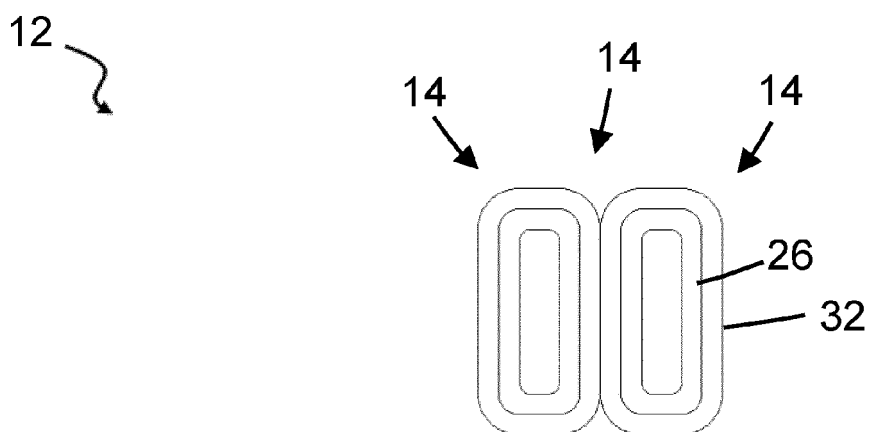


Fig. 9A

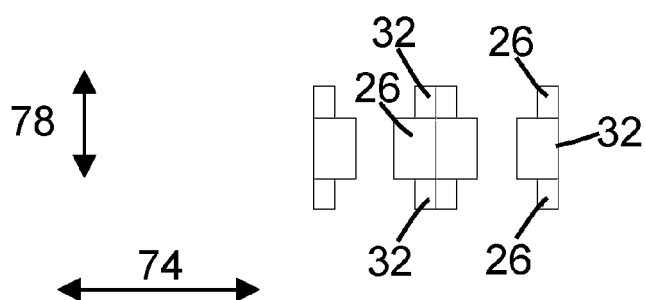


Fig. 9B

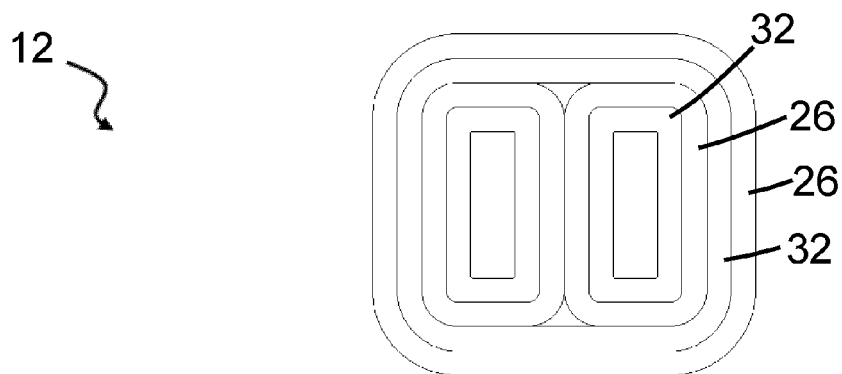


Fig. 10A

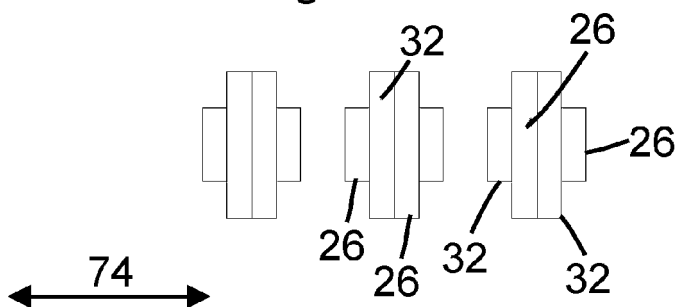


Fig. 10B

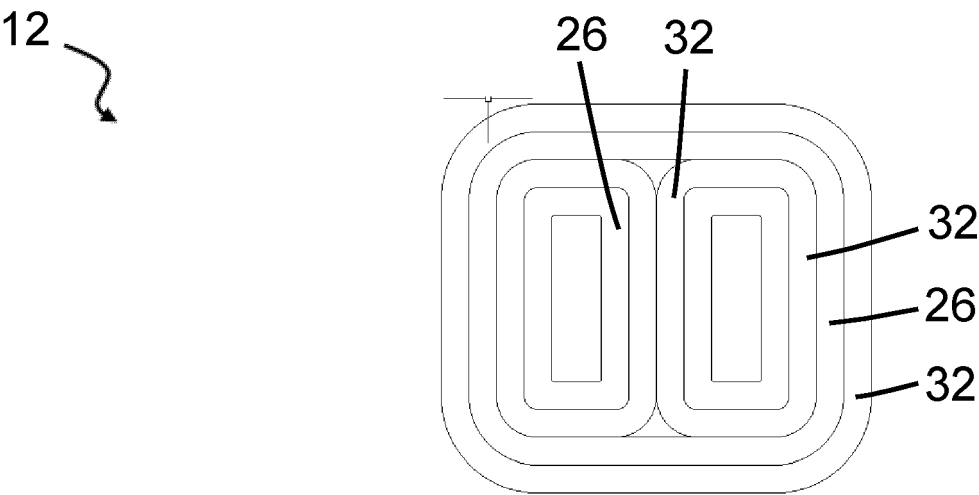


Fig. 11A

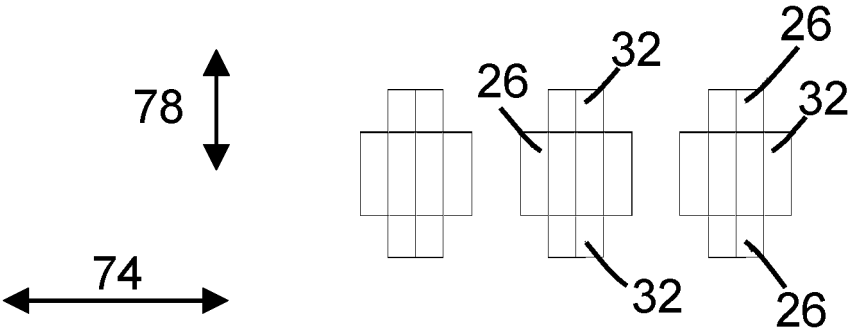


Fig. 11B



EUROPEAN SEARCH REPORT

Application Number

EP 23 20 5659

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 10 978 237 B2 (HITACHI LTD [JP]) 13 April 2021 (2021-04-13) * column 3, line 45 - column 5, line 20; figures 1,2 * * column 5, line 65 - column 3, line 3 * * claim 1 * -----	1-6, 9, 10, 13-15	INV. H01F3/10 H01F27/245 H01F27/25 H01F27/26
A	US 2013/219700 A1 (HURST JOHN SHIRLEY [US] ET AL) 29 August 2013 (2013-08-29) * paragraph [0016] - paragraph [0021] * * paragraph [0054] - paragraph [0056] * * figure 10 * -----	1-15	
A	US 2018/218826 A1 (MILLSAP JAMES [DE]) 2 August 2018 (2018-08-02) * paragraph [0030] * -----	1, 15	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01F
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		17 April 2024	Tano, Valeria
CATEGORY OF CITED DOCUMENTS			
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 23 20 5659

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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17-04-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 10978237 B2	13-04-2021	JP 6937584 B2	22-09-2021
		JP 2018133352 A	23-08-2018
		TW 201830424 A	16-08-2018
		US 2018233267 A1	16-08-2018
US 2013219700 A1	29-08-2013	AU 2010211030 A1	28-07-2011
		BR PI1008233 A2	08-03-2016
		CA 2751556 A1	12-08-2010
		CN 102362321 A	22-02-2012
		CO 6420381 A2	16-04-2012
		EA 201190077 A1	30-11-2012
		JP 2012517119 A	26-07-2012
		PE 20120682 A1	06-07-2012
		US 2010194515 A1	05-08-2010
		US 2013219700 A1	29-08-2013
		WO 2010090717 A1	12-08-2010
US 2018218826 A1	02-08-2018	CN 108028120 A	11-05-2018
		EP 3320546 A1	16-05-2018
		US 2018218826 A1	02-08-2018
		WO 2017008833 A1	19-01-2017

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2019123797 A1 [0004] [0005] [0023] [0053]