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(54) **WINDING ASSEMBLY FOR A TRANSFORMER AND METHOD FOR MANUFACTURING A WINDING ASSEMBLY FOR A TRANSFORMER**

(57) The present disclosure relates to a winding assembly (110) for a transformer (10) including at least one first winding (112) configured to be wound about a core (14) of the transformer (10), at least one second winding (118) configured to be wound around the first winding (112), the first winding (112) and the second winding (118) being spaced apart from each other in a radial direction (R) by at least one gap (122), and at least one securing device (126) connected to the first winding (112)

and the second winding (118) by a material-bond (128) to secure the first winding (112) to the second winding (118) to reduce movement of the first winding (112) and the second winding (118) relative to each other, the securing device (126) being arranged in the gap (122) to partially occupy the gap (122). The present disclosure also relates to a method for manufacturing a winding assembly (110).

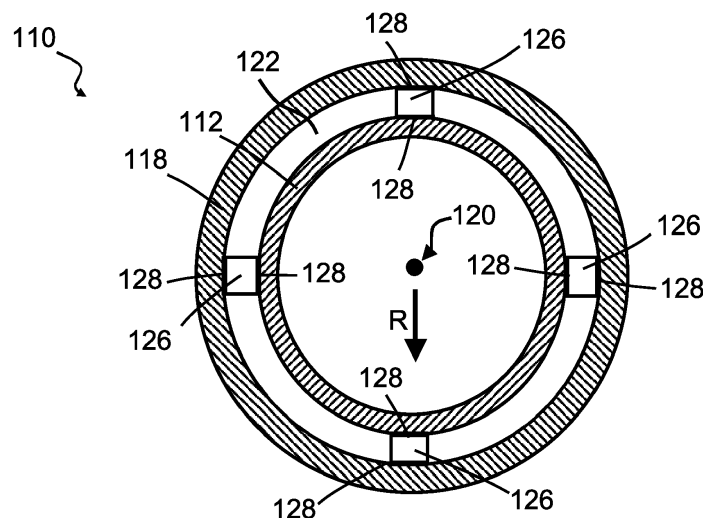


Fig. 3

Description

Background

[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. A transformer generally achieves such a voltage conversion by employing a plurality of windings which include electrical conductors and are wound around a core of the transformer by a plurality of turns.

[0002] Transformers may be subjected to one or more forces, in particular one or more transient forces, which may occur during operation of the respective transformer. For instance, a short circuit of one or more windings of the transformer may generate relatively high forces at the windings which may displace the windings. Many transformers include one or more clamping devices which provide an axial clamping force to counteract such forces and reduce movement of one or more windings of the transformer which may be caused by these forces, e.g., during a short circuit of windings of the transformer.

[0003] However, the known clamping devices have several drawbacks. For instance, the clamping devices are often relatively bulky and consume a relatively large amount of space. Moreover, due to the relatively large amount of heat which may be generated by the transformer during operation, the clamping devices are generally required to be made of one or more materials which are resistant to relatively high temperatures, e.g., 155° C or more, which are often relatively expensive. Moreover, mounting the clamping devices on the respective transformer can be time-consuming and labor-intensive.

[0004] In addition, the known clamping devices are generally required to conform to a geometry of the windings, e.g., to the helical shape of the windings, at an interface between the clamping devices and the windings of the transformer. For this purpose, in many instances, an additional adapter is required at the interface between the clamping devices and the windings of the transformer and where the adapter is adapted to the shape of the windings, which further exacerbates the disadvantages of the known clamping devices.

[0005] Thus, the present disclosure describes one or more aspects for providing improved means for coping with forces generated at the windings of a transformer, as detailed below.

[0006] The present disclosure relates to a winding assembly for a transformer according to a first aspect of the disclosure.

[0007] According to a second aspect of the disclosure, a method for manufacturing a winding assembly for a transformer is described.

[0008] 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 methods and 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.

[0009] 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.

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

Description of the Drawings

[0011]

Fig. 1 schematically shows, in a cross-sectional view, a short circuit state of a transformer;

Fig. 2 schematically shows, in a cross-sectional view, a further short circuit state of a transformer;

Fig. 3 shows, in a schematic axial view, a winding assembly according to an embodiment of the present disclosure;

Fig. 4 shows, in a schematic axial view, a winding assembly according to a further embodiment of the present disclosure.

[0012] In the following, exemplary embodiments of the disclosure will be described. It is noted that some aspects of any one of the described embodiments may also be found in some other embodiments unless otherwise stated or obvious. However, for increased intelligibility, each aspect will only be described in detail when first mentioned and any repeated description of the same aspect will be omitted.

[0013] The winding assembly according to the first aspect of the present disclosure may include at least one first winding configured to be wound at least partially around at least one core of a transformer and at least one second winding configured to be wound at least partially around the at least one first winding. The at least

one first winding and the at least one second winding may be spaced apart from each other in a radial direction by at least one gap. The winding assembly may further include at least one securing device. The securing device may be connected to the at least one first winding and the at least one second winding, respectively, by a material-bond to at least partially secure the at least one first winding to the at least one second winding to reduce movement of the at least one first winding and the at least one second winding relative to each other. The at least one securing device may be at least partially arranged in the at least one gap to partially occupy the at least one gap.

[0014] The material-bond between the securing device and the at least one first winding and the at least one second winding, respectively, may provide relatively sturdy and space-efficient means for connecting the at least one first winding to the at least one second winding in order to reduce movement of the at least one first winding and the at least one second winding relative to each other. By contrast, the known clamping devices are relatively bulky and therefore consume a relatively large amount of space. Moreover, the drawback of the relatively large size of the clamping devices are further exacerbated since the clamping devices are generally arranged outside of, in particular at least above and below, the windings, with respect to a winding axis of the windings. The material-bond between the securing device and the at least one first winding and the at least one second winding, respectively, according to the present disclosure utilizes the space(s), i.e., the at least one gap, between the at least one first winding and the at least one second winding. Since one or more gaps are often provided in transformers between adjacent windings, e.g., for cooling purposes, no, or at least less, additional space outside of the at least one first winding and the at least one second winding is occupied by the at least one securing device and the material-bond(s) described herein. This may provide a relatively compact solution for securing the at least one first winding and the at least one second winding to reduce movement of the at least one first winding and the at least one second winding relative to each other compared with known clamping devices.

[0015] Hence, providing a material-bond between the securing device and the at least one first winding and the at least one second winding, respectively, may entirely replace the known clamping devices. Alternatively, one or more clamping devices may still be included in the embodiments described herein to provide an additional securing means for (further) reducing movement of the at least one first winding and the at least one second winding relative to each other. In this case, the material-bond between the securing device and the at least one first winding and the at least one second winding, respectively, may allow the requirements of the clamping device(s), e.g., the amount of force the clamping device(s) should withstand, to be reduced.

[0016] Material-bonding the at least one first winding

and the at least one second winding by means of the at least one securing device may provide an essentially monolithic construction of the at least one first winding and the at least one second winding at least at the securing device(s). In particular, a contiguous material connection may thereby be provided, at least in a radial direction of the winding assembly, e.g., from an innermost winding, e.g., of the at least one first winding, to an outermost winding, e.g., of the at least one second winding, of the winding assembly. This may allow a transmission of one or more forces, in particular shear forces, through at least a portion of the winding assembly, in particular throughout the winding assembly, at least at the securing device(s), in particular including between each layer of a plurality layers of the at least one first winding and the at least one second winding, if present.

[0017] A "material-bond", within the context of the present disclosure, may be any bond or connection using molecular or atomic bonding forces between at least two components, i.e., between the at least one first winding and the at least one second winding. The material-bond may be provided by applying at least one material-bonding process and/or one or material-bonding substances, for example by melting and solidifying, welding, gluing, etc. The material-bond may be provided by using at least one additive, for example at least one welding additive and/or at least one adhesive. Alternatively, the material-bond may be provided without the use of additives, i.e., additive-free, e.g., by at least partially melting or curing at least one of the securing device(s), the at least one first winding and the at least one second winding at an interface between the securing device and the respective winding(s) to fuse the securing device to the respective winding(s).

[0018] As stated above, the material-bond may include at least one adhesive. In other words, the securing device may be adhesively connected, by means of the at least one adhesive, to the at least one first winding and the at least one second winding, respectively. The at least one adhesive may be applied to one or more surfaces of the securing device, in particular to the entire surface(s) at an interface between the securing device and the at least one first winding and the at least one second winding, respectively, prior to mounting the securing device in the respective gap(s). This may allow the adhesive to be pre-applied to the securing device. This may allow the bonding forces between the securing device and the at least one first winding and the at least one second winding, respectively, to be optimized and/or maximized, e.g., by efficiently optimizing and/or maximizing an amount of adhesive to an available area of the surfaces at an interface between the securing device and the at least one first winding and the at least one second winding, respectively, while minimizing adverse effects which the adhesive may have on, e.g., impregnation with at least one liquid, in particular a dielectric liquid, in particular oil and/or ester oil, of the at least one first winding and the at least one second winding, e.g., of an insulation material of the at

least one first winding and the at least one second winding, which may maximize and/or allow sufficient impregnation of the at least one first winding and the at least one second winding, e.g., of an insulation material of the at least one first winding and the at least one second winding. Impregnating the insulation material with at least one liquid may improve the dielectric properties of the insulation material. Hence, an insufficient impregnation of the insulation material may have adverse effects on the insulating properties of the insulation material and/or the insulation material and/or the operation of the transformer which is to be prevented by sufficient impregnation.

[0019] The at least one first winding and the at least one second winding may each be wound about at least one winding axis. In particular, the at least one first winding and the at least one second winding may each be wound about a common winding axis. The at least one gap may be annular or semi-annular shaped and may extend about the at least one winding axis of the at least one first winding and/or the at least one second winding. The at least one first winding and the at least one second winding may be arranged radially offset from each other, with respect to the at least one winding axis of the at least one first winding and/or the at least one second winding. In other words, the at least one first winding may be arranged at least partially radially within the at least one second winding and spaced radially from the at least one second winding by the at least one gap.

[0020] The at least one gap may extend axially along at least a portion of the at least one first winding and/or the at least one second winding, in particular along the winding axis of the at least one first winding and/or the at least one second winding. The at least one gap may be a single coherent gap provided between the at least one first winding and the at least one second winding. Alternatively, the at least one gap may include a plurality of at least partially separated gaps between the at least one first winding and the at least one second winding.

[0021] The at least one gap may have one or more dimensions which are substantially uniform across the at least one gap, e.g., the at least one gap may have a constant gap width which defines a distance between the at least one first winding and the at least one second winding in the radial direction. Alternatively, or additionally, the at least one gap may have one or more dimensions which vary across different sections of the at least one gap. For instance, the gap width of the at least one gap may vary across different sections of the at least one gap. In other words, one or more first sections of the at least one gap may have a different gap width than one or more second sections of the at least one gap.

[0022] The at least one gap may be at least one hollow space in which the securing device takes up, i.e., occupies, only a portion of the hollow space. The at least one gap may be at least partially configured as a cooling channel configured to at least partially receive at least one fluid, in particular at least one liquid, in particular oil and/or

ester oil, and/or at least one gas, e.g., air, to provide cooling to at least a portion of the at least one first winding and/or the at least one second winding. The transformer may be configured as a liquid-immersed transformer or as a dry-type transformer.

[0023] In addition to the at least one gap arranged between the at least one first winding and the at least one second winding, the at least one first winding and/or the at least one second winding may each include a plurality of layers, wherein adjacent layers of the plurality of layers may be spaced apart from each other by at least one second gap. In this case, at least one securing device may also be arranged at least partially in the at least one second gap between adjacent layers, respectively, to partially occupy the at least one second gap and may be connected to each of the adjacent layers of the at least one first winding and the at least one second winding, respectively, to reduce movement of the adjacent layers relative to each other.

[0024] The above-identified feature that "the at least one securing device may be at least partially arranged in the at least one gap to partially occupy the at least one gap" means that at least a section of the securing device may be arranged in the at least one gap. In other words, only one or more sections of the at least one securing device may be arranged in the at least one gap, i.e., one or more sections of the at least one securing device may be arranged outside of the at least one gap, or the entire respective securing device may be arranged within the at least one gap. In either case, the at least one securing device may only partially occupy the at least one gap. In other words, even if the entire securing device is arranged within the gap, the gap includes one or more spaces, in particular one or more empty or hollow spaces, which the securing device does not occupy. Thus, a portion of the at least one gap may remain hollow, even with the securing device(s) arranged at least partially in the at least one gap. This may allow at least one cooling fluid, e.g., a gas, such as air, or a liquid or oil, which is received in the at least one gap, to more effectively and/or efficiently at least partially cool the at least one first winding and/or the at least one second winding.

[0025] A plurality of securing devices may be provided and connected to the at least one first winding and the at least one second winding, respectively, by a material-bond to at least partially secure the at least one first winding to the at least one second winding. Each securing device may be at least partially arranged in the at least one gap to partially occupy the at least one gap. The winding assembly may include a plurality of securing devices arranged in at least partially separate gaps within the winding assembly, i.e., a plurality of securing devices may be arranged in a gap between adjacent windings and/or a plurality of securing devices may be arranged in a gap between adjacent layers of a winding, e.g., of the at least one first winding and/or the at least one second winding. The plurality of securing devices may be separated and/or distanced from each other. In particu-

lar, at least some, in particular all of, the plurality of securing devices may be unconnected from each other.

[0026] The securing device may be configured to reduce movement of the at least one first winding and the at least one second winding relative to each other in one or more directions and/or about one or more axes. For instance, the securing device may be configured to reduce translational movement of the at least one first winding and the at least one second winding relative to each other at least in an axial direction, i.e., along the winding axis of the at least one first winding and/or the at least one second winding. Alternatively, or additionally, the securing device may be configured to reduce translational movement of the at least one first winding and the at least one second winding relative to each other at least in the radial direction. Alternatively, or additionally, the securing device may be configured to reduce rotational movement of the at least one first winding and the at least one second winding relative to each other, e.g., about a longitudinal axis and/or about the winding axis of the at least one first winding and/or the at least one second winding.

[0027] The at least one first winding may be a low voltage (LV) winding and the at least one second winding may be a HV winding, the HV winding having a voltage which is higher than the voltage of the LV winding, or vice versa. The transformer may be configured as a traction transformer, in which case the at least one first winding may be a low voltage (LV) winding, also referred to as a "traction winding", and the at least one second winding may be a HV winding.

[0028] The at least one first winding may be a primary winding and the at least one second winding may be a secondary winding, or vice versa. The primary winding(s) may be connected to a source of voltage and the secondary winding(s) may be connected to a load, or vice versa.

[0029] The term "reduce", within the context of the above-identified feature that movement of the at least one first winding and the at least one second winding relative to each other is reduced, may mean that an extent of movement, e.g., a distance of movement and/or a degree of rotation, of the at least one first winding and the at least one second winding relative to each other in one or more directions and/or about one or more axes is decreased, compared with a state of the transformer in which the securing device is not included. However, some movement of the at least one first winding and the at least one second winding relative to each other may be permitted. Alternatively, "reduce" may mean that all movement in one or more directions and/or about one or more axes is substantially prevented.

[0030] The at least one securing device may be at least partially hollow. In other words, the at least one securing device may define at least one lumen therein. The lumen may be configured to receive a fluid, in particular a gas, e.g., air, and/or a liquid, e.g., water and/or oil, e.g., for cooling the at least one first winding and/or the at least one second winding. Alternatively, the securing device

may be entirely solid. The at least one securing device may be at least partially rigid and/or incompressible and/or non-extensible. The at least one securing device is not limited to having a particular shape. In particular, the shape of the at least one securing device may be adapted to the desired and/or required strength of the at least one securing device, e.g., depending on the forces at the windings of the transformer which the securing device is required to withstand.

[0031] The transformer, for which the winding assembly described herein is used, may be a low voltage (LV), medium voltage (MV) or high voltage (HV) transformer. The transformer may be configured as a liquid-cooled, e.g., a liquid-immersed, such as an oil-filled or oil-immersed, transformer. Alternatively, the transformer may be configured as a dry-type transformer, e.g., not immersed in a liquid, e.g., oil.

[0032] The at least one first winding and the at least one second winding may include at least one electrical conductor covered in at least one electrically insulating material, particularly aramid. The at least one securing device may be material-bonded to the at least one electrically insulating material.

[0033] The at least one securing device may be configured as a spacer configured to at least partially separate the at least one first winding from the at least one second winding, in particular by a substantially predefined distance. Thus, the at least one securing device may be configured to substantially maintain the at least one gap between the at least one first winding from the at least one second winding, in particular at a substantially constant value at a location of the respective at least one securing device. The at least one securing device may be configured to substantially maintain, or at least limit, the at least one gap between the at least one first winding and the at least one second winding by withstanding forces which may urge the at least one gap to be increased, i.e., which may cause movement of the at least one first winding and the at least one second winding away from each other at the location of the at least one securing device, with the aid of the material-bond.

[0034] Alternatively, or additionally, the at least one securing device may be configured to substantially maintain, or at least limit, the at least one gap between the at least one first winding and the at least one second winding by withstanding forces which may urge the at least one gap to be decreased, i.e., which may cause movement of the at least one first winding and the at least one second winding towards each other at the location of the at least one securing device. In other words, the at least one securing device may be configured to withstand compression forces and/or tensile forces between the at least one first winding and the at least one second winding. Alternatively, or additionally, the at least one securing device may be configured to withstand shear forces and/or bending forces which may be exerted onto the at least one securing device by the at least one first winding and/or the at least one second winding.

[0035] The material-bond may include at least one adhesive, in particular at least one curable adhesive, in particular at least one curable resin. The adhesive may be curable by heat, light, in particular UV light, and/or pressure. The at least one adhesive may be applied to at least a portion of an interface between the at least one securing device and the at least one first winding and the at least one second winding, respectively. In particular, the entire interface, e.g., an entire interface surface, between the at least one securing device and the at least one first winding and the at least one second winding, respectively, may be covered in adhesive to provide a relatively strong and durable material-bond between the at least one securing device and the at least one first winding and the at least one second winding, respectively, to withstand relative movement between the at least one first winding and the at least one second winding. However, providing the at least one adhesive on only a portion of the interface, e.g., a portion of an interface surface, between the at least one securing device and the at least one first winding and the at least one second winding, respectively, may be sufficient, depending on the magnitude of forces which the material-bond is required to withstand. For instance, at least 60%, in particular at least 70%, in particular at least 80%, in particular at least 90%, of an interface surface between the at least one securing device and the at least one first winding and the at least one second winding, respectively, may be covered in adhesive.

[0036] The present disclosure is not limited to a particular type of adhesive. The adhesive may be selected based on its adhesion strength, depending on the application, e.g., the amount of forces the material-bond should withstand. The adhesive may be applied having a layer thickness which is selected based on the desired and/or required adhesion strength of the material-bond, depending on the application, e.g., the amount of forces the material-bond should withstand.

[0037] The at least one adhesive, in its raw state at room temperature (20° C), may be a liquid or a paste or a gel having a viscosity which allows the adhesive to be distributed on respective one or more surfaces. This may allow the adhesive to be individually applied and distributed according to the respective size and/or shape of an interface between the at least securing device and the at least one first winding and the at least one second winding, respectively, e.g., at least one surface of the at least one securing device which interfaces the at least one first winding and the at least one second winding, when the at least one securing device is connected to the at least one first winding and the at least one second winding, respectively.

[0038] Alternatively, the adhesive may be provided in solid or higher viscosity form, e.g., on at least one single-sided or double-sided tape and/or sheet which may be coated with the adhesive and applied to the at least one securing device and/or to the at least one first winding and/or to the at least one second winding.

[0039] The movement of the at least one first winding and the at least one second winding, which is reduced by the at least one securing device, may include a movement caused by a short circuit of the at least one first winding and/or the at least one second winding.

[0040] The at least one securing device may be configured and arranged to reduce movement of the at least one first winding and the at least one second winding relative to each other at least in an axial direction along a winding axis about which the at least one first winding and/or the at least one second winding is/are wound. Such movement of the at least one first winding and the at least one second winding relative to each other in an axial direction along the winding axis may result in shear forces which act on the material-bond between the at least one securing device and the at least one first winding and the at least one second winding, respectively. A material-bond, in particular an adhesive bond, is particularly suitable for withstanding shear forces which may result in a relatively stable and sturdy connection between the at least one securing device and the at least one first winding and the at least one second winding, respectively, with respect to such a load situation of the at least one first winding and the at least one second winding.

[0041] The at least one first winding and/or the at least one second winding may be configured to be secured to the core of the transformer by at least one material-bond, in particular by at least one adhesive, in particular by at least one curable adhesive, in particular by at least one curable resin. This may allow the at least one first winding and the at least one second winding, which are interconnected to a single coherent unit via the at least one securing device and the material-bond(s), to be secured to the core.

[0042] The material-bond may include at least one B-stage adhesive. A B-stage adhesive is understood as being an adhesive which is only partially cured, i.e., cross-linked, in certain conditions, e.g., at room temperature, e.g., at 20° C. The B-stage adhesive may then, after applying the B-stage adhesive to one or more desired surfaces, be fully cured, e.g., by providing an elevated temperature to the B-stage adhesive, e.g., by heating the B-stage adhesive, and/or by providing pressure to the B-stage adhesive. Configuring the adhesive to be a B-stage adhesive may facilitate the pre-application of the adhesive and/or may provide a more durable and sturdy material-bond between the at least one securing device and the at least one first winding and the at least one second winding, respectively. Pre-application of the adhesive may facilitate manufacturing processes since the adhesive application can be done in a separate step from the winding step or steps.

[0043] The material-bond(s) may be configured and arranged to withstand one or more forces which may be caused by and/or during the operation of the transformer and/or one or more forces which are related to the operation of the transformer, such as vibration(s) and/or one

or more forces and/or one or more shock forces which are transferred from an environment to the transformer, e.g., by a vehicle, e.g., acceleration forces of a vehicle, in and/or on which the transformer is mounted. Alternatively, or additionally, the material-bond(s) may be configured and arranged to withstand forces, in particular shock forces and/or vibrations, which may be caused by a short circuit of the at least one first winding and/or the at least one second winding.

[0044] The material-bond may be configured and arranged to withstand forces, in particular in an axial direction along a winding axis and/or in a radial direction with respect to the winding axis, about which the at least one first winding and/or the at least one second winding is/are wound, of up to 50 kN, particularly up to 100 kN, more particularly up to 150 kN, more particularly up to 200 kN, more particularly up to 250 kN, more particularly up to 300 kN, more particularly up to 350 kN, more particularly up to 400 kN, more particularly up to 450 kN, more particularly up to 500 kN, more particularly up to 550 kN, more particularly up to 600 kN. The forces in the axial direction along a winding axis may result in a shear load on the material-bond.

[0045] The transformer may be configured as a traction transformer, in particular for providing power to a vehicle, in particular a rail-bound vehicle, in particular as an on-board traction transformer.

[0046] At least 60%, particularly at least 65%, more particularly at least 70%, more particularly at least 75%, more particularly at least 80%, more particularly at least 85%, more particularly at least 90%, more particularly at least 95%, of an area of a surface of the at least one securing device facing the at least one first winding may be covered by at least one adhesive. Alternatively, or additionally, at least 60%, particularly at least 65%, more particularly at least 70%, more particularly at least 75%, more particularly at least 80%, more particularly at least 85%, more particularly at least 90%, more particularly at least 95%, of an area of a surface of the at least one securing device facing the at least one second winding may be covered by at least one adhesive.

[0047] An area of a surface of the at least one securing device facing the at least one first winding may be no more than 500 square centimetres (cm²), particularly no more than 450 cm², more particularly no more than 400 cm², more particularly no more than 350 cm², more particularly no more than 300 cm², more particularly no more than 250 cm², more particularly no more than 200 cm², more particularly no more than 150 cm², more particularly no more than 100 cm². Alternatively, or additionally, an area of a surface of the at least one securing device facing the at least one second winding may be no more than 500 cm², particularly no more than 450 cm², more particularly no more than 400 cm², more particularly no more than 350 cm², more particularly no more than 300 cm², more particularly no more than 250 cm², more particularly no more than 200 cm², more particularly no more than 150 cm², more particularly no more than 100 cm².

The above-mentioned surface of the at least one securing device facing the at least one first winding and/or the at least one second winding, respectively, may be a surface, in particular the entire surface, at a connection interface between the at least one securing device and the at least one first winding and/or the at least one second winding, respectively. Limiting an area of the surface, in particular the entire surface, at the connection interface between the at least one securing device and the at least one first winding and/or the at least one second winding, respectively, e.g., per the value(s) provided above, may minimize adverse effects which the at least one securing device, in particular the material-bond, e.g., adhesive, may have on, e.g., impregnation of the at least one first winding and the at least one second winding, e.g., of an insulation material of the at least one first winding and the at least one second winding, which may maximize and/or allow sufficient impregnation of the at least one first winding and the at least one second winding, e.g., of an insulation material of the at least one first winding and the at least one second winding. In particular, an azimuthal width of the at least one securing device at the connection interface may be relatively small and an impregnation liquid can flow underneath the at least one securing device in an azimuthal direction inside the insulation material to impregnate it.

[0048] The winding assembly may include a plurality of first windings, which may be electrically interconnected, and/or a plurality of second windings, which may be electrically interconnected. The plurality of first windings may be stacked in an axial direction along a winding axis of the first windings. Alternatively, or additionally, the plurality of second windings may be stacked in an axial direction along a winding axis of the second windings. Such a configuration including stacked windings may exacerbate the load and/or movement of the windings in the transformer, in particular during a short circuit of the at least one first winding and/or the at least one second winding. In case one of the stacked windings, e.g., one of the plurality of first windings, short circuits, there is a high current only in the short circuited winding and in the at least one second winding, or vice versa. Since the mean positions of a current in the short circuited winding and the at least one second winding, or vice versa, are different, one or more relatively large forces, in particular one or more repulsive forces, may be generated in an axial direction, e.g., along the winding axis of the winding(s). Hence, providing the at least one securing device to reduce movement of the at least one first winding and the at least one second winding relative to each other may provide a relatively reliable, sturdy and compact means for coping with forces on the windings in such a configuration, in particular during a short circuit of one of the windings.

[0049] The material-bond may be configured and arranged to withstand movement of the at least one first winding and the at least one second winding, relative to each other, which is caused by forces, e.g., electromag-

netically induced forces, during operation of the transformer. For instance, such forces may include vibration(s), short-circuit forces and/or forces which are transferred from an environment to the transformer, e.g., by a vehicle, e.g., acceleration forces of a vehicle, in and/or on which the transformer is mounted.

[0050] The present disclosure further relates to a transformer, in particular a traction transformer, which may comprise at least one core and at least one winding assembly according to any configuration described herein. The at least one first winding may be wound at least partially around the at least one core and the at least one second winding may be wound at least partially around the at least one first winding.

[0051] The at least one first winding and/or the at least one second winding may be secured to the at least one core by a material-bond, in particular by at least one adhesive, in particular at least one curable adhesive, in particular at least one curable resin.

[0052] The present disclosure further relates a vehicle, in particular a vehicle configured to transport one or more objects, in particular a rail-bound vehicle, the vehicle including a transformer according to any configuration described herein. The transformer may be configured as a traction transformer to provide power to the vehicle, in particular as an onboard traction transformer.

[0053] The method for manufacturing a winding assembly for a transformer according to the second aspect of the present disclosure may comprise:

(a) arranging the at least one securing device at least partially in at least one gap which spaces the at least one first winding and the at least one second winding apart from each other in a radial direction such that the at least one securing device partially occupies the gap.

[0054] The method may further comprise:

(b) securing the at least one first winding to the at least one second winding to reduce movement of the at least one first winding and the at least one second winding relative to each other by connecting the at least one securing device to the at least one first winding and to the at least one second winding, respectively, by a material-bond.

[0055] The at least one first winding and/or the at least one second winding may be wound at least partially about the core of the transformer. Alternatively, the at least one first winding and/or the at least one second winding may be pre-wound, e.g., about a bobbin, and arranged on the core as a pre-wound unit, respectively. The at least one securing device may be connected to the at least one first winding and the at least one second winding by the material-bond prior to arranging the at least one first winding and/or the at least one second winding at least partially about the core. In particular, the at least one first winding and the at least one second winding, which are interconnected by the at least one securing device, may

be pre-mounted to a coherent unit which is placed at least partially about the core of the transformer. This may allow the winding assembly, including the at least one first winding and the at least one second winding which are interconnected by the at least one securing device, to be handled as a coherent unit which may facilitate moving the winding assembly, e.g., to a point of installation in the transformer, and/or mounting the winding assembly.

[0056] In step (b), the at least one securing device may be connected to the at least one first winding and to the at least one second winding, respectively, by at least one adhesive, in particular at least one curable adhesive, in particular at least one curable resin.

[0057] The method may further comprise:

(c) curing the at least one adhesive, in particular by applying heat and/or light and/or pressure to the adhesive.

[0058] The at least one adhesive may be cured in a process, in particular in which heat is applied at least to a portion of the winding assembly, for providing a further function during manufacturing of the winding assembly or the transformer. The "further function" may relate to a function provided to the winding assembly or the transformer during manufacturing which is provided independently from the solution disclosed herein relating to the at least one securing device for securing the at least one first winding to the at least one second winding, e.g., in winding assemblies or transformers which are known from the prior art. In other words, one or more process steps which are already applied to at least some of the winding assemblies or transformers which are known from the prior art can be used to cure the adhesive. For instance, in many cases, at least one process step is provided for drying (i.e. removal of moisture upon heating and /or the application of reduced pressure to at least one portion of the transformer), e.g., for drying the core and/or insulation material of the transformer. Hence, such one or more process steps which are already provided may be utilized, rather than, or in addition to, providing one or more separate or additional process steps for curing the adhesive. This may provide an efficient way of curing the adhesive.

[0059] The at least one adhesive may be applied to at least one surface of the at least one securing device, in particular prior to step (a).

[0060] The adhesive may be applied to at least one surface of the at least one securing device which faces the at least one first winding and/or to at least one surface of the securing device which faces the at least one second winding, based in a state in which the at least one first winding, the at least one second winding and the at least one securing device have been assembled.

[0061] The at least one adhesive may be applied to the at least one first winding and/or the at least one second winding, in particular to an insulation material of the at least one first winding and/or an insulation material of the at least one second winding, in particular prior to step (a).

[0062] The at least one first winding and the at least

one second winding may include at least one electrical conductor covered in at least one electrically insulating material, particularly aramid. The at least one adhesive and the at least one electrically insulating material may be applied to the at least one first winding and/or the at least one second winding simultaneously.

[0063] The at least one adhesive may be applied as a coating, in particular a coating which is uninterrupted and/or uniform. Alternatively, the at least one adhesive may be applied as a coating, in particular a coating which covers only a fraction of the surface and/or may comprise a certain pattern.

[0064] The method may further comprise:

securing the at least one first winding and/or the at least one second winding to the core of the transformer by a material-bond, particularly by at least one adhesive.

[0065] The following list of aspects provides alternative and/or further features of the disclosure:

1. A winding assembly for a transformer, the winding assembly including:

at least one first winding configured to be wound at least partially around at least one core of the transformer,

at least one second winding configured to be wound at least partially around the at least one first winding, wherein the at least one first winding and the at least one second winding are spaced apart from each other, in particular in a radial direction, by at least one gap; and

at least one securing device which is configured to at least partially secure the at least one first winding to the at least one second winding and which is connected to the at least one first winding and/or the at least one second winding, respectively, by a material-bond, in particular to reduce movement of the at least one first winding and the at least one second winding relative to each other, the at least one securing device being arranged at least partially in the at least one gap, in particular to partially occupy the at least one gap.

2. The winding assembly according to aspect 1, wherein the at least one gap is at least partially configured as a cooling channel configured to at least partially receive at least one fluid, in particular at least one liquid, to provide cooling to at least a portion of the at least one first winding and/or the at least one second winding.

3. The winding assembly according to aspect 1 or 2, wherein the at least one securing device is configured as a spacer configured to at least partially separate the at least one first winding from the at least one second winding, in particular by a substantially predefined distance.

4. The winding assembly according to any of the preceding aspects, wherein the material-bond includes at least one adhesive, in particular at least one curable adhesive, in particular at least one curable resin.

5. The winding assembly according to any of the preceding aspects, wherein the movement of the at least one first winding and the at least one second winding which is reduced by the at least one securing device, includes a movement caused by a short circuit of the at least one first winding and/or the at least one second winding.

6. The winding assembly according to any of the preceding aspects, wherein the at least one securing device is configured and arranged to reduce movement of the at least one first winding and the at least one second winding relative to each other at least in an axial direction along a winding axis about which the at least one first winding and/or the at least one second winding is/are wound.

7. The winding assembly according to any of the preceding aspects, wherein the at least one first winding and/or the at least one second winding is/are configured to be secured to the core of the transformer by a material-bond, in particular by at least one adhesive, in particular by at least one curable adhesive, in particular by at least one curable resin.

8. The winding assembly according to any of the preceding aspects, wherein the material-bond includes at least one B-stage adhesive.

9. The winding assembly according to any of the preceding aspects, wherein the material-bond is configured and arranged to withstand forces caused by a short circuit of the at least one first winding and/or the at least one second winding.

10. The winding assembly according to any of the preceding aspects, wherein the material-bond is configured and arranged to withstand forces in an axial direction along a winding axis, about which the at least one first winding and/or the at least one second winding is/are wound, of up to 50 kN, particularly up to 100 kN, more particularly up to 150 kN, more particularly up to 200 kN, more particularly up to 250 kN, more particularly up to 300 kN.

11. The winding assembly according to any of the preceding aspects, wherein the transformer is configured as a traction transformer, in particular for providing power to a vehicle, in particular a rail-bound vehicle, in particular as an onboard traction transformer.

12. The winding assembly according to any of the

preceding aspects, wherein:

at least 60% of an area of a surface of the at least one securing device facing the at least one first winding is covered by at least one adhesive; 5
and/or
at least 60% of an area of a surface of the at least one securing device facing the at least one second winding is covered by at least one adhesive. 10

13. The winding assembly according to any of the preceding aspects, wherein:

an area of a surface of the at least one securing device facing the at least one first winding is no more than 500 square centimetres (cm²), particularly no more than 450 cm², more particularly no more than 400 cm², more particularly no more than 350 cm², more particularly no more than 300 cm², more particularly no more than 250 cm², more particularly no more than 200 cm², more particularly no more than 150 cm², more particularly no more than 100 cm². 15
and/or 25
an area of a surface of the at least one securing device facing the at least one second winding is no more than 500 cm², particularly no more than 450 cm², more particularly no more than 400 cm², more particularly no more than 350 cm², more particularly no more than 300 cm², more particularly no more than 250 cm², more particularly no more than 200 cm², more particularly no more than 150 cm², more particularly no more than 100 cm². 30 35

14. The winding assembly according to any of the preceding aspects, including a plurality of first windings and/or a plurality of second windings, wherein: 40

the plurality of first windings are stacked in an axial direction along a winding axis of the first windings; 45
and/or
the plurality of second windings are stacked in an axial direction along a winding axis of the second windings.

15. A transformer, in particular a traction transformer, comprising at least one core and at least one winding assembly according to any of the preceding aspects, wherein the at least one first winding is wound at least partially around the at least one core and the at least one second winding is wound at least partially around the at least one first winding. 50 55

16. The transformer according to aspect 15, wherein the at least one first winding and/or the at least one

second winding is/are secured to the at least one core by a material-bond, in particular by at least one adhesive, in particular at least one curable adhesive, in particular at least one curable resin.

17. The transformer according to aspect 15 or 16, wherein the transformer is configured as a liquid-immersed transformer.

18. A vehicle, in particular a vehicle configured to transport one or more objects, in particular a rail-bound vehicle, the vehicle including a transformer according to any of aspects 15 to 17, wherein the transformer is configured as a traction transformer to provide power to the vehicle, in particular as an onboard traction transformer.

19. A method for manufacturing a winding assembly for a transformer, in particular a winding assembly according to any of aspects 1 to 14, the method comprising:

(a) arranging the at least one securing device at least partially in at least one gap which spaces the at least one first winding and the at least one second winding apart from each other in a radial direction, in particular such that the at least one securing device partially occupies the gap, 5
(b) securing the at least one first winding to the at least one second winding by means of the at least one securing device, in particular by connecting the at least one securing device to the at least one first winding and/or to the at least one second winding, respectively, by a material-bond, in particular to reduce movement of the at least one first winding and the at least one second winding relative to each other. 10

20. The method according to aspect 19, wherein, in step (b), the at least one securing device is connected to the at least one first winding and to the at least one second winding, respectively, by at least one adhesive, in particular at least one curable adhesive, in particular at least one curable resin.

21. The method according to aspect 20, further including:
(c) curing the at least one adhesive, in particular by applying heat and/or light and/or pressure to the adhesive.

22. The method according to aspect 21, wherein the at least one adhesive is cured in a process, in particular in which heat is applied at least to a portion of the winding assembly, for providing a further function during manufacturing of the winding assembly or the transformer. More specifically, the heat applied to cure the adhesive is used to dry the winding

assembly or the transformer.

23. The method according to any of aspects 20 to 22, wherein the at least one adhesive is applied to at least one surface of the at least one securing device, in particular prior to step (a).

24. The method according to any of aspects 20 to 23, wherein the at least one adhesive is applied to the at least one first winding and/or the at least one second winding, in particular to an insulation material of the at least one first winding and/or an insulation material of the at least one second winding, in particular prior to step (a).

25. The method according to any of aspects 20 to 24, wherein the at least one first winding and/or the at least one second winding is/are made of at least one electrical conductor covered in at least one electrically insulating material, and wherein the at least one adhesive and the at least one electrically insulating material may be applied to the at least one first winding and/or the at least one second winding simultaneously.

26. The method according to any of aspects 23 to 25, wherein the at least one adhesive is applied as a coating, in particular a coating which is an uninterrupted and/or uniform. Alternatively, the at least one adhesive may be applied as a coating, in particular a coating which covers only a fraction of the surface and/or may comprise a certain pattern.

27. The method according to any of aspects 19 to 26, further including:
securing the at least one first winding and/or the at least one second winding to the core of the transformer by a material-bond, particularly by at least one adhesive.

[0066] Fig. 1 schematically shows, in a cross-sectional view, a short circuit state of a transformer 10. The transformer 10 includes at least one first winding 12 configured to be wound at least partially around at least one leg 13 of at least one core 14 of the transformer 10 and at least one second winding 18 configured to be wound at least partially around the at least one first winding 12. In the particular configuration shown in Fig. 1, the at least one first winding 12 and the at least one second winding 18 are wound about a common winding axis 20. Alternatively, the at least one first winding 12 and the at least one second winding 18 may be wound about respective winding axes which do not coincide. The winding axis 20 may coincide with a longitudinal axis of the at least one leg 13, as shown in Fig. 1

[0067] The at least one first winding 12 may be a low voltage (LV) winding and the at least one second winding 18 may be a high voltage (HV) winding, the HV winding

having a voltage which is higher than the voltage of the LV winding. Alternatively, the at least one first winding 12 may be an HV winding and the at least one second winding 18 may be an LV winding. The transformer 10 may be configured as a traction transformer, in which case the at least one first winding 12 may be a low voltage (LV) winding, also referred to as a "traction winding".

[0068] The at least one first winding 12 and the at least one second winding 18 may be spaced apart from each other in a radial direction R by at least one gap 22. During certain operating situations, one or more forces F may act on the at least one first winding 12 and/or the at least one second winding 18 and urge the at least one first winding 12 and/or the at least one second winding 18 to move, in particular axially along the axis 20. The forces F indicated in Fig. 1, in particular their magnitude and direction, are only exemplary. The forces F may urge the at least one first winding 12 and the at least one second winding 18 to move, relative to each other, in opposite directions along the axis 20. Alternatively, the forces F may urge the at least one first winding 12 and the at least one second winding 18 to move in the same direction along the axis 20, in which case the forces F acting on the at least one first winding 12 and the forces F acting on the at least one second winding 18 may have different values which may urge the at least one first winding 12 and the at least one second winding 18 to move relative to each other. Alternatively, forces may act on the at least one first winding 12, while substantially no forces act on the at least one second winding 18, or vice versa.

[0069] For instance, during a short circuit of the at least one first winding 12 and/or the at least one second winding 18, one or more forces may act on the at least one first winding 12 and/or the at least one second winding 18 to urge the at least one first winding 12 and/or the at least one second winding 18 to move, in particular axially along the axis 20.

[0070] As mentioned at the beginning, many transformers include one or more clamping devices which provide an axial clamping force to counteract the above-mentioned forces and reduce movement of one of more windings of the respective transformer which may be caused by these forces, e.g., during a short circuit of at least one of the windings of the transformer.

[0071] However, the known clamping devices have several drawbacks, as detailed at the beginning. Thus, an improved means for coping with forces generated at the windings of a transformer 10 is provided in the present disclosure, as detailed below and shown in Fig. 3.

[0072] In the further configuration shown in Fig. 2, the at least one first winding 12 includes a plurality of windings 12A and 12B which are stacked in an axial direction along the axis 20. Such a configuration may exacerbate movement of the windings 12, 18 in the transformer 10. In case one of the windings 12A and 12B of the at least one first winding 12 short circuits, there may be a relatively high current only in the short circuited winding 12A or 12B and in the at least one second winding 18. Since

the mean positions of a current in the short circuited winding 12A or 12B and the at least one second winding 18 are different, one or more relatively large forces F , in particular one or more repulsive forces, are generated in an axial direction along the axis 20, as shown in exemplary manner in Fig. 2.

[0073] Alternatively, or additionally, the at least one second winding 18 may include a plurality of windings which may be stacked in an axial direction along the axis 20 or a different axis.

[0074] Fig. 3 shows a winding assembly 110 according to an embodiment of the present disclosure in axial view. The winding assembly 110 includes at least one first winding 112 configured to be wound at least partially around at least one core of a transformer, e.g., as shown in Figs. 1 or 2. The at least one first winding 112 may be identical or similar to the at least one first winding 12 of Figs. 1 or 2. The winding assembly 110 may further include at least one second winding 118 configured to be wound at least partially around the at least one first winding 112. The at least one second winding 118 may be identical or similar to the at least one second winding 18 of Figs. 1 or 2.

[0075] The at least one first winding 112 and the at least one second winding 118 are spaced apart from each other in a radial direction R by at least one radial gap 122, which is similar or identical to the configuration shown in Figs. 1 or 2. The at least one gap 122 may be a cooling channel configured to at least partially receive at least one fluid, in particular at least one liquid, to provide cooling to at least a portion of the at least one first winding 112 and/or the at least one second winding 118.

[0076] The winding assembly 110 may further include at least one securing device 126 which is connected to the at least one first winding 112 and the at least one second winding 118, respectively, by a material-bond 128. The winding assembly 110 according to the embodiment shown in Fig. 3 includes four securing devices 126. However, this is only exemplary. The winding assembly 110 may include any number of securing devices 126, i.e., a single securing device 126 or two, three, or more than four securing devices 126, or even more securing devices 126, such as at least 10, more particular at least 20, more particular at least 30, more particular at least 40, more particular at least 50, more particular at least 60, more particular at least 70, more particular at least 80, more particular at least 90, more particular at least 100 securing devices 126, etc. The securing device(s) 126 may be arranged at any location in the at least one gap 122.

[0077] The at least one securing device 126 may be configured to at least partially secure the at least one first winding 112 to the at least one second winding 118, via the material-bonds 128, to reduce movement of the at least one first winding 112 and the at least one second winding 118 relative to each other. The at least one securing device 126 may be arranged at least partially in the at least one gap 122 to partially occupy the at least

one gap 122. The at least one securing device 126 may only partially be arranged in the at least one gap 122. Alternatively, one or more securing devices 126 may be arranged in the at least one gap 122. In either case, the respective at least one securing device 126 may only partially occupy the at least one gap 122. In other words, even if the entire securing device 126, or each entire securing device 126 if a plurality of securing devices 126 are provided, is arranged in the at least one gap 122, the at least one gap 122 may include one or more spaces, in particular one or more empty or hollow spaces, which are not occupied by the at least one securing device 126. Thus, a portion of the at least one gap 122 may remain hollow, even with the at least one securing device 126 being arranged partially or entirely in the at least one gap 122. This may allow the at least one gap 122 to receive at least one cooling fluid, e.g., a gas, such as air, or a liquid or oil, to provide cooling to the at least one first winding 112 and/or the at least one second winding 118.

[0078] The at least one securing device 126 may be configured as a spacer configured to at least partially separate the at least one first winding 112 from the at least one second winding 118, in particular by a substantially predefined distance.

[0079] The material-bond(s) 128 may include at least one adhesive, in particular at least one curable adhesive, in particular at least one curable resin. In particular, the material-bond(s) 128 may include at least one B-stage adhesive.

[0080] Additionally, the at least one first winding 112 and/or the at least one second winding 118 may be secured to the core of the transformer, in particular to at least one leg of the core of the transformer, by one or more securing means, in particular by a material-bond, particularly by at least one adhesive. This may allow the at least one first winding 112 and the at least one second winding 118, which is configured as a coherent unit via the material-bonded connections of the at least one securing device 126 to the at least one first winding 112 and the at least one second winding 118, to be fixed to the core of the transformer.

[0081] The at least one securing device 126 may be elongate to extend along the axis 120, which represents a winding axis, about which the at least one first winding 112 and/or the at least one second winding 118 are wound, and/or a longitudinal axis of the winding assembly 110. This may provide a relatively large interface between the at least one securing device 126 and the at least one first winding 112 and the at least one second winding 118, respectively, which may allow a relatively large surface of the at least one securing device 126 to be material-bonded to the at least one first winding 112 and the at least one second winding 118, respectively. For instance, the at least one securing device 126 may have a length of at least 10 cm, in particular at least 15 cm, in particular at least 20 cm, which may extend along the axis 120.

[0082] The at least one first winding 112 and/or the at

least one second winding 118 may be wound about at least one core of the transformer, e.g., the at least one core 14 of the transformer 10 shown in Figs. 1 and 2. In such a configuration, the at least one securing device 126 may be connected to the at least one first winding 112 and the at least one second winding 118 via the material-bonds in a state in which the at least one first winding 112 and the at least one second winding 118 have been wound about the at least one core 14 of the transformer 10.

[0083] Alternatively, the at least one first winding 112 and/or the at least one second winding 118 may be pre-wound, e.g., about a bobbin, and arranged on the at least one core as a pre-wound unit, respectively. In such a pre-wound configuration, the at least one securing device 126 may be connected to the at least one first winding 112 and/or the at least one second winding 118 by the material-bond 128 prior to arranging the at least one first winding 112 and/or the at least one second winding 118 about the at least one core. In particular, the at least one first winding 112 and the at least one second winding 118, which are interconnected by the at least one securing device 126, may be pre-mounted to a coherent unit which is then placed at least partially about the at least one core of the transformer. This may allow the winding assembly 110, including the at least one first winding 112 and the at least one second winding 118 which are interconnected by the at least one securing device 126, to be handled as a coherent unit which may facilitate moving the winding assembly 110, e.g., to a point of installation in the transformer, and/or mounting the winding assembly 110. However, even in such a pre-wound configuration of the at least one first winding 112 and/or the at least one second winding 118, the at least one securing device 126 may be connected to the at least one first winding 112 and the at least one second winding 118 via the material-bonds in a state in which the at least one first winding 112 and the at least one second winding 118 have been arranged about the at least one core 14 of the transformer 10.

[0084] To provide the material-bonds 128, at least one bonding substance, e.g., at least one adhesive, e.g., at least one resin, e.g., at least one B-stage resin, may be applied to at least one surface of the at least one securing device 126 which is at a respective interface between the at least one securing device 126 and the at least one first winding 112 and the at least one second winding 118, when the at least one securing device 126 is connected to the at least one first winding 112 and the at least one second winding 118, respectively. Alternatively, or additionally, at least one bonding substance, e.g., at least one adhesive, e.g., at least one resin, e.g., at least one B-stage resin, may be applied to at least one surface of the at least one first winding 112 and/or the at least one second winding 118 which is at a respective interface between the at least one securing device 126 and the at least one first winding 112 and the at least one second winding 118, when the at least one securing de-

vice 126 is connected to the at least one first winding 112 and the at least one second winding 118, respectively.

[0085] In addition to the at least one gap 122 arranged between the at least one first winding 112 and the at least one second winding 118, the at least one first winding 112 and/or the at least one second winding 118 may include a plurality of layers 112A, 112B, 118A, 118B, as shown in Fig. 4, wherein adjacent layers of the plurality of layers 112A, 112B, 118A, 118B may also be spaced apart from each other by at least one second gap 123, 125. In this case, at least one securing device 126 may also be arranged at least partially in the at least one second gap 123, 125 between adjacent layers 112A, 112B, 118A, 118B, respectively, to partially occupy the at least one second gap 123, 125 and may be connected to each of the adjacent layers 112A, 112B, 118A, 118B of the at least one first winding 112 and the at least one second winding 118, respectively. The number of layers 112A, 112B, 118A, 118B, as shown in Fig. 4 is only exemplary. The at least one first winding 112 and the at least one second winding 118 may include any number of layers. Alternatively, or additionally, the at least one first winding 112 and/or the at least one second winding 118 may include a plurality of turns (not shown in the Figs.), in particular which are arranged along the winding axis 120.

[0086] The at least one securing device 126 may be configured in any shape and/or size suitable for arranging the at least one securing device 126 in the at least one gap 122, 123, 125. The sizes and shapes of the securing devices 126 shown in Figs. 3 and 4 are only exemplary. Moreover, in case a plurality of securing devices 126 are provided, as shown in Figs. 3 and 4, the securing devices 126 may vary in their configuration and/or type, e.g., in their sizes and/or shapes and/or material. In other words, one or more first securing devices 126 of the plurality of securing devices 126 may have a different configuration and/or different type, e.g., different sizes and/or shapes and/or material, than one or more second securing devices 126 of the plurality of securing devices 126.

[0087] Moreover, the winding assembly 110 may include a plurality of first windings 112 and/or a plurality of second windings 118, similar or identical to the configuration shown in Fig. 2. The plurality of first windings 112 may be stacked in an axial direction, e.g., along the winding axis 120 of the first windings 112. Alternatively, or additionally, the plurality of second windings 118 may be stacked in an axial direction, e.g., along the winding axis 120 of the second windings 118.

[0088] The at least one first winding 112 and the at least one second winding 118 may each include at least one electrical conductor covered in at least one electrically insulating material, particularly aramid, which is not specifically shown in Fig. 3. The at least one securing device 126 may be material-bonded to the at least one electrically insulating material of the at least one first winding 112 and the at least one second winding 118. Further insulation material may be provided, e.g., between the at least one first winding 112 and the at least

one second winding 118, i.e., in addition to the insulating material covering the at least one electrical conductor. For instance, one or more sheets of insulating material may be provided between the at least one first winding 112 and the at least one second winding 118, i.e., in addition to the insulating material covering the at least one electrical conductor.

[0089] While various embodiments of the present disclosure have been described above, it should be understood that they have been presented by way of example only, and not by way of limitation. Likewise, the various diagrams may depict an example architectural or configuration, which are provided to enable persons of ordinary skill in the art to understand exemplary features and functions of the present disclosure. Such persons would understand, however, that the present disclosure is not restricted to the illustrated example architectures or configurations, but can be implemented using a variety of alternative architectures and configurations. Additionally, as would be understood by persons of ordinary skill in the art, one or more features of one embodiment can be combined with one or more features of another embodiment described herein. Thus, the breadth and scope of the present disclosure should not be limited by any of the above-described exemplary embodiments.

[0090] It is also understood that any reference to an element herein using a designation such as "first," "second," and so forth does not generally limit the quantity or order of those elements. Rather, these designations can be used herein as a convenient means of distinguishing between two or more elements or instances of an element. Thus, a reference to first and second elements does not mean that only two elements can be employed, or that the first element must precede the second element in some manner.

[0091] Various modifications to the implementations described in this disclosure will be readily apparent to those skilled in the art, and the general principles defined herein can be applied to other implementations without departing from the scope of this disclosure. Thus, the disclosure is not intended to be limited to the implementations shown herein, but is to be accorded the widest scope consistent with the novel features and principles disclosed herein, as recited in the claims below.

Claims

1. A winding assembly (110) for a transformer (10), the winding assembly (110) including:

at least one first winding (112) configured to be wound at least partially around at least one core (14) of the transformer (10),

at least one second winding (118) configured to be wound at least partially around the at least one first winding (112), wherein the at least one first winding (112) and the at least one second

winding (118) are spaced apart from each other in a radial direction (R) by at least one gap (122); and

at least one securing device (126) which is connected to the at least one first winding (112) and the at least one second winding (118), respectively, by a material-bond (128) to at least partially secure the at least one first winding (112) to the at least one second winding (118) to reduce movement of the at least one first winding (112) and the at least one second winding (118) relative to each other, the at least one securing device (126) being arranged at least partially in the at least one gap (122) to partially occupy the at least one gap (122).

2. The winding assembly (110) according to claim 1, wherein the at least one gap (122) is at least partially configured as a cooling channel configured to at least partially receive at least one fluid, in particular at least one liquid, to provide cooling to at least a portion of the at least one first winding (112) and/or the at least one second winding (118).
3. The winding assembly (110) according to claim 1 or 2, wherein the at least one securing device (126) is configured as a spacer configured to at least partially separate the at least one first winding (112) from the at least one second winding (118), in particular by a substantially predefined distance.
4. The winding assembly (110) according to any of the preceding claims, wherein the material-bond includes at least one adhesive, in particular at least one curable adhesive, in particular at least one curable resin.
5. The winding assembly (110) according to any of the preceding claims, wherein the movement of the at least one first winding (112) and the at least one second winding (118) which is reduced by the at least one securing device, includes a movement caused by a short circuit of the at least one first winding (112) and/or the at least one second winding (118).
6. The winding assembly (110) according to any of the preceding claims, wherein the at least one securing device (126) is configured and arranged to reduce movement of the at least one first winding (112) and the at least one second winding (118) relative to each other at least in an axial direction along a winding axis (120) about which the at least one first winding (112) and/or the at least one second winding (118) is/are wound.
7. The winding assembly (110) according to any of the preceding claims, wherein the at least one first winding (112) and/or the at least one second winding

(118) is/are configured to be secured to the core (14) of the transformer (10) by a material-bond, in particular by at least one adhesive, in particular by at least one curable adhesive, in particular by at least one curable resin.

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8. The winding assembly (110) according to any of the preceding claims, wherein the material-bond (128) includes at least one B-stage adhesive.

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9. The winding assembly (110) according to any of the preceding claims, wherein the material-bond (128) is configured and arranged to withstand forces in an axial direction along a winding axis (120), about which the at least one first winding (112) and/or the at least one second winding (118) is/are wound, of up to 50 kN, particularly up to 100 kN, more particularly up to 150 kN, more particularly up to 200 kN, more particularly up to 250 kN, more particularly up to 300 kN.

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10. The winding assembly (110) according to any of the preceding claims, including a plurality of first windings (112) and/or a plurality of second windings (118), wherein:

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the plurality of first windings (112) are stacked in an axial direction along a winding axis (120) of the first windings (112);

and/or

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the plurality of second windings (118) are stacked in an axial direction along a winding axis (120) of the second windings (118).

11. The winding assembly (110) according to any of the preceding claims, wherein the material-bond (128) is configured and arranged to withstand movement of the at least one first winding (112) and the at least one second winding (118), relative to each other, which is caused by forces during operation of the transformer.

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12. A method for manufacturing a winding assembly (110) for a transformer (10), in particular a winding assembly (110) according to any of claims 1 to 11, the method comprising:

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(a) arranging the at least one securing device (126) at least partially in at least one gap (122) which spaces the at least one first winding (112) and the at least one second winding (118) apart from each other in a radial direction (R) such that the at least one securing device (126) partially occupies the at least one gap (122), and
(b) securing the at least one first winding (112) to the at least one second winding (118) to reduce movement of the at least one first winding (112) and the at least one second winding (118)

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relative to each other by connecting the at least one securing device (126) to the at least one first winding (112) and to the at least one second winding (118), respectively, by a material-bond (128).

13. The method according to claim 12, wherein, in step (b), the at least one securing device (126) is connected to the at least one first winding (112) and to the at least one second winding (118), respectively, by at least one adhesive, in particular at least one curable adhesive, in particular at least one curable resin, and wherein the method further includes:
(c) curing the at least one adhesive, in particular by applying heat and/or light and/or pressure to the adhesive,
wherein optionally the at least one adhesive is cured in a process, in particular in which heat is applied at least a portion of the winding assembly (110), for providing a further function during manufacturing of the winding assembly (110) or the transformer (10).

14. The method according to any of claims 12 or 13, wherein the at least one adhesive is applied to at least one surface of the at least one securing device (126), in particular prior to step (a).

15. The method according to any of claims 12 to 14, wherein the at least one adhesive is applied as a coating, in particular a coating which is an uninterrupted and/or uniform.

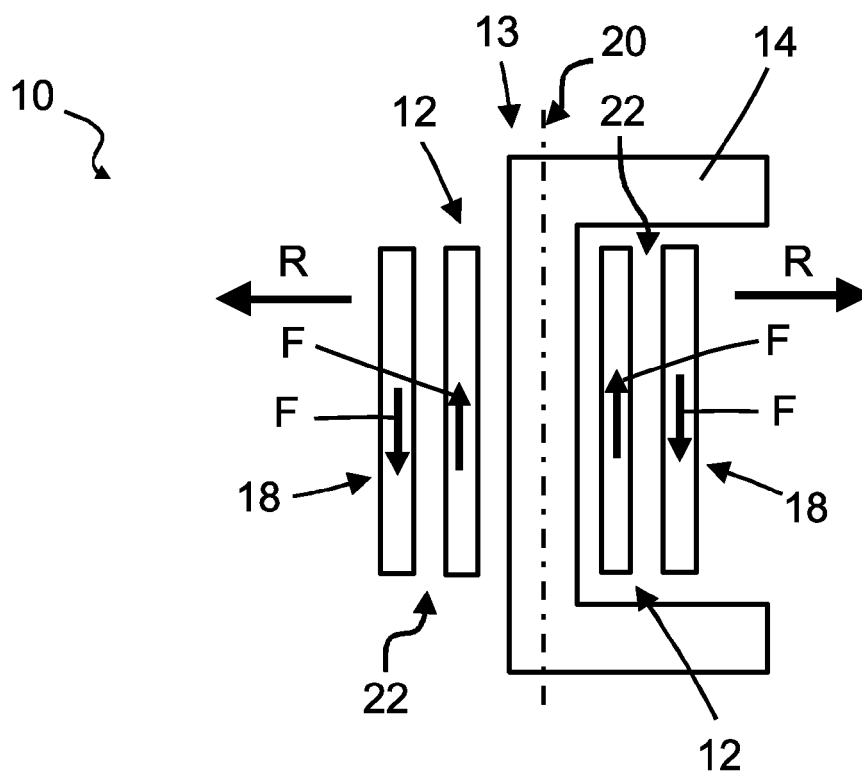


Fig. 1

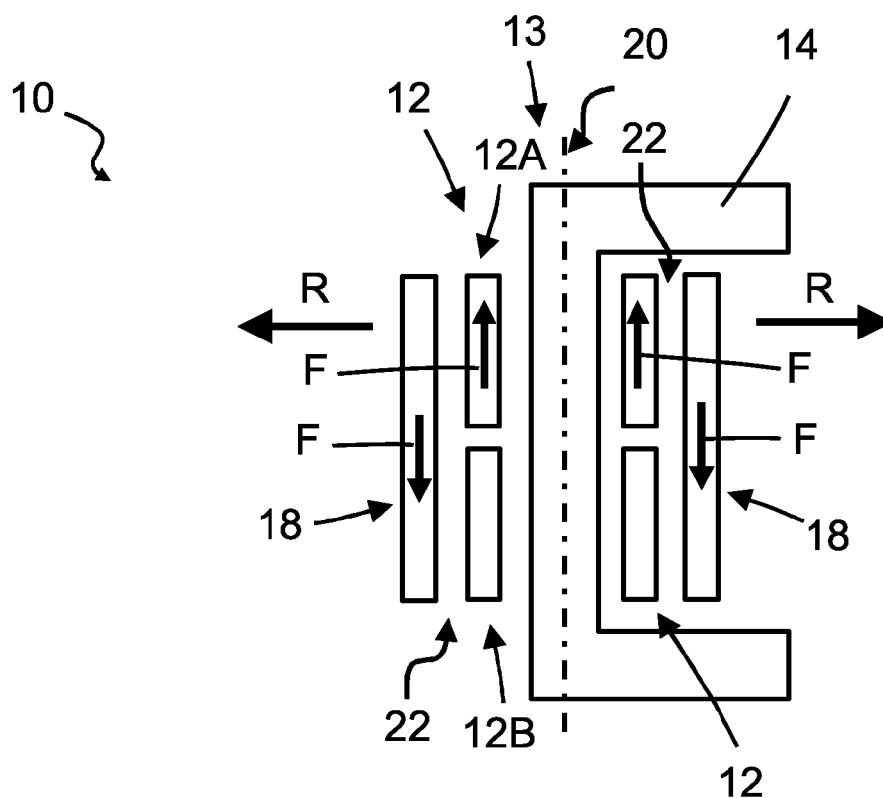


Fig. 2

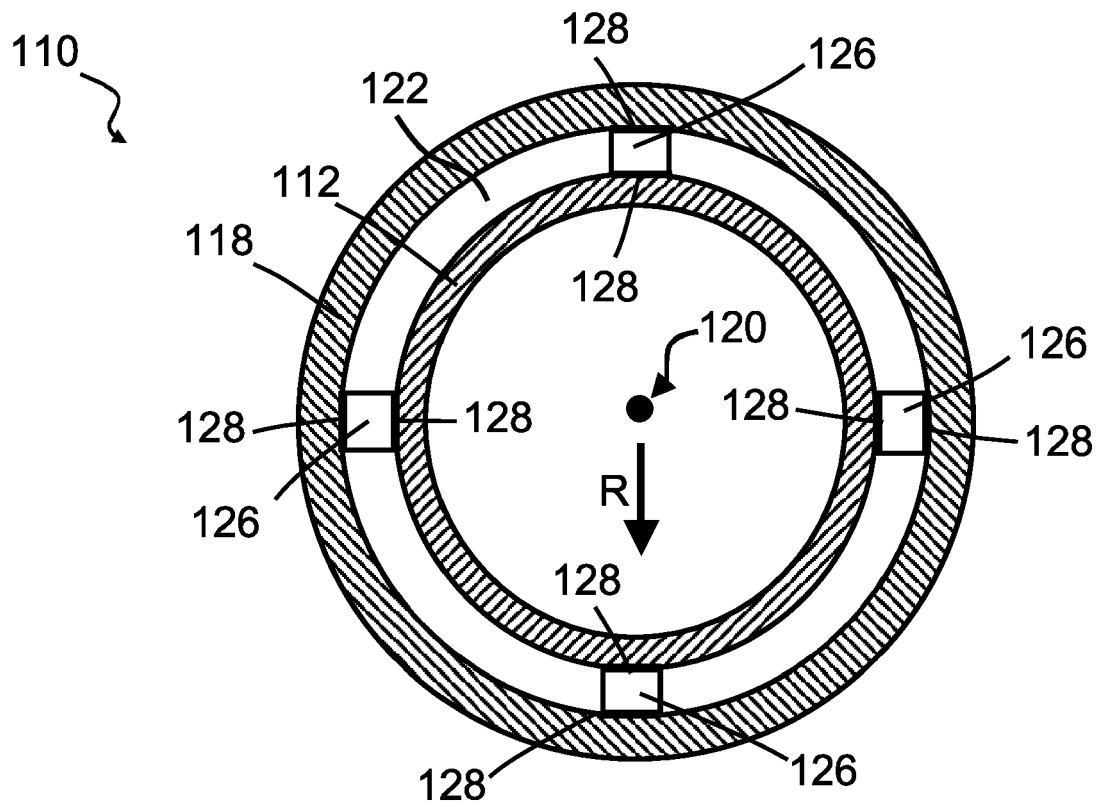


Fig. 3

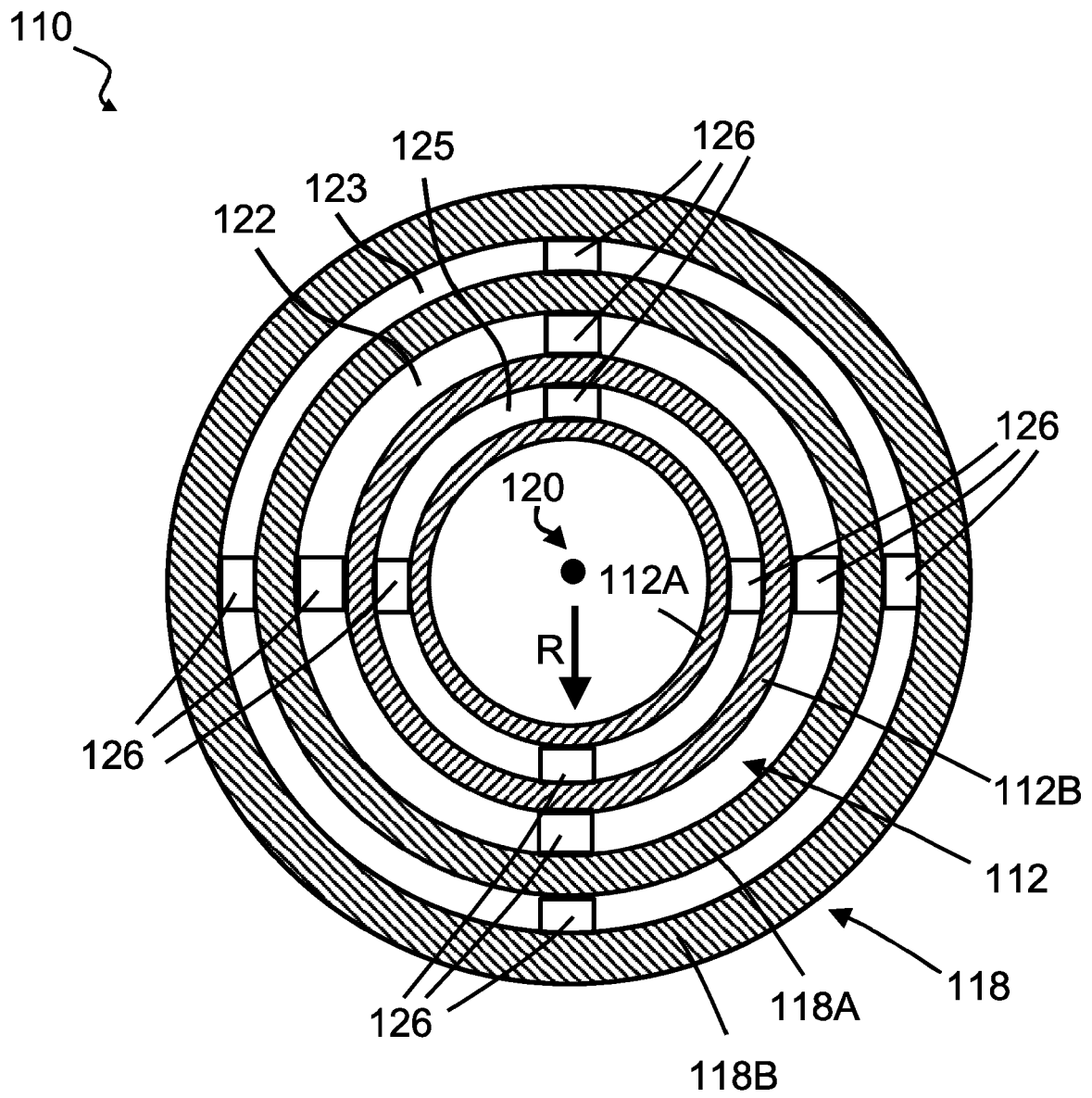


Fig. 4



EUROPEAN SEARCH REPORT

Application Number

EP 22 21 3156

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 25 May 2023	Examiner Brächer, Thomas
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 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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25-05-2023

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