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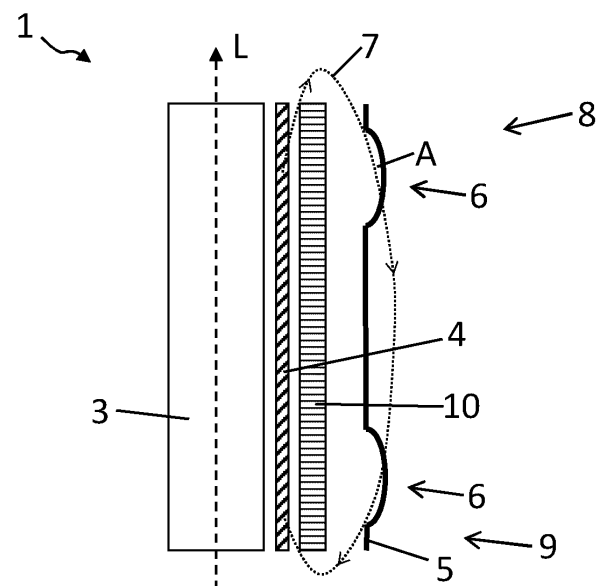
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(54) **TRANSFORMER**

(57) A transformer (1) comprises a core (3) and at least one winding (4, 10) for transforming current electromagnetically, wherein the at least one winding (4, 10) encloses the core (3) with respect to a lateral direction (B, C) of the transformer (1) and the core (3) and the winding (4, 10) are configured to cause a predetermined magnetic flux during operation of the transformer (1). The transformer (1) further comprises a housing (2) enclosing the core (3) and the winding (4, 10) with respect to the lateral direction (B, C) of the transformer (1) such that the winding (4, 10) is arranged between the core (3) and the housing (2). The housing (2) comprises an outer wall (5) with at least one curved portion (6) that is formed in coordination with magnetic field lines (7) of the magnetic flux of the transformer (1) that arises during operation.

Fig. 7



Description

[0001] The present disclosure is related to a transformer.

[0002] Transformers are used to transfer an output voltage of an electrical circuit to an input voltage for another electrical circuit. Transformers comprise an active part including windings which are closed in a tank or housing. In general, it is a challenge to increase the efficiency of a transformer.

[0003] Embodiments of the present disclosure relate to a transformer that enable reliable operation and an improvement in efficiency and that contribute to keep operation noise low.

[0004] According to an embodiment, a transformer comprises at least a core and at least one winding for transforming current or voltage electromagnetically, wherein the at least one winding surrounds the core with respect to a lateral direction of the transformer and the core and the winding are configured to cause a predetermined magnetic flux during operation of the transformer. The transformer further comprises a housing that encloses the core and the winding with respect to the lateral direction of the transformer such that the winding is arranged between the core and the housing. The housing comprises an outer wall with at least one curved portion that is formed in coordination with magnetic field lines of the magnetic flux of the transformer that arises during operation.

[0005] Due to the described configuration with one or more curved portions at a respective outer wall a transformer is feasible that enables reliable operation and an improvement in efficiency and that further contributes to keep operation noise low.

[0006] It is a finding of the present disclosure that conventional designs of a transformer comprise active parts closed in a tank with rectangular shape with substantially flat walls. Arising stray magnetic flux of the transformer induces eddy currents in the tank wall which leads to losses in performance of the transformer. In addition, the stray magnetic flux and the induced eddy currents interaction leads to load noise.

[0007] By use of the described transformer configuration with one or more curved portions adapted in coordination with the specific magnetic field characteristics of the transformer it is feasible to reduce the eddy currents in a wall of the housing, e.g. by 1% or more or even 5% or more compared to a conventional design without curved surfaces on outer wall. It is further possible to keep the performance losses and a load noise generation low. Moreover, the described configuration enables to keep the noise generation low so as to reduce a source of vibrations and sound propagation resulting in an annoying hum. There is no need for additional elements placed at a tank wall to reduce losses and/or noise generation. However, additional elements can be applied to even improve loss reduction. The one or more curved portions are formed by deliberate shaping of the outer wall using

predetermined curvatures overall or at one or more strategic locations where a higher density of the magnetic field lines is to be expected to penetrate the housing or the outer wall. Thus, the described configuration of the transformer contributes to minimize or alter the eddy current effect on the housing walls.

[0008] According to an embodiment of the transformer, the curved portion comprises a predetermined radius of curvature, e.g. formed in coordination with a height of the outer wall. For example, the radius of curvature is given as 1% to 50% of the height of the outer wall. The height of the transformer or the outer wall of the transformer housing can have a value between 0.2 m and 20 m, for example. Alternatively or additionally, the radius of curvature can be given with 1 cm or greater or 10 cm or greater, or 20 cm or greater. Alternatively or additionally, the curved portion comprises a predetermined radius of curvature of 10000 cm or smaller, or of 5000 cm or smaller or of 200 cm or smaller. Moreover, the curved portion can comprise more than one given radius of curvature and/or there can be two or more separate curved portions formed at a respective outer wall of the housing comprising different or the same radii of curvature.

[0009] According to a further embodiment of the transformer, the outer wall comprises two or more curved portions spaced apart from each other, wherein one curved portion is formed in an upper region of the outer wall and another curved portion is formed in a lower region of the outer wall with respect to a longitudinal axis of the transformer across the lateral direction. The outer wall can be formed flat between the two curved portions or can comprise one or more further curved portions.

[0010] According to a further embodiment of the transformer, the outer wall comprises an overall convex shape with respect to a longitudinal direction of the transformer across the lateral direction such that a distance between the winding and a middle portion of the outer wall is bigger than a distance between the winding and an upper region and a distance between the winding and a bottom region of the outer wall. Thus, the curved portions can form the entire outer wall at a respective side of the housing.

[0011] According to a further embodiment of the transformer, the at least one curved portion is formed circumferentially surrounding at the outer walls of the housing. The housing can be formed cube-shaped or cuboid-shaped and hence comprising a top wall, a bottom wall and four outer walls. Alternatively, the housing can be formed cylindrical with a circular or ellipsoidal outer wall with respect to a cross section along the lateral directions.

[0012] According to a further embodiment of the transformer, the at least one curved portion is formed with a hemi-spherical or semi-ellipsoidal shape.

[0013] According to a further embodiment, the transformer comprises two or more windings surrounding the core or an associated further core. At least one winding is configured to operate at a voltage of 1 kV or above. For example, one winding is configured to operate at a relative low voltage within a range of 100 V and 1000 kV,

and a further winding is configured to operate at a relative high voltage within a range of 1 kV and 2000 kV. The material of the core(s) can be a ferromagnetic material, e.g. silicon steel, ferrite and/or amorphous magnetic material. The material of the winding(s) can be aluminum and/or copper conductor wrapped in an insulating material, e.g. paper. The housing or the outer wall of the transformer can comprise a material with a conductivity of 100000 S/m or greater and a thickness of 1 mm up to 25 mm, for example.

[0014] Exemplary embodiments are explained in the following with the aid of schematic drawings and reference numbers. The figures show:

Figures 1-9 embodiments of a transformer in different views.

[0015] The accompanying figures are included to provide a further understanding. It is to be understood that the embodiments shown in the figures are illustrative representations and are not necessarily drawn to scale. Identical reference numbers designate elements or components with identical functions. In so far as elements or components correspond to one another in terms of their function in different figures, the description thereof is not repeated for each of the following figures. For the sake of clarity elements might not appear with corresponding reference symbols in all figures possibly.

[0016] Figure 1 illustrates an embodiment of a transformer 1 in a perspective view. The transformer 1 comprises a core 3 and at least one winding 4 for transforming current electromagnetically. The at least one winding 4 encloses or surrounds the core 3 with respect to a lateral directions B, C of the transformer 1 and the core 3 and the winding 4 are configured to cause a predetermined magnetic flux during operation of the transformer 1.

[0017] The transformer 1 further comprises a housing 2 that encloses the core 3 and the winding 4 with respect to the lateral directions B, C such that the winding 4 is arranged between the core 3 and the housing 2. The housing 2 comprises an outer wall 5 with a curved portion 6 that is formed in coordination with magnetic field lines 7 of the magnetic flux of the transformer 1 that arises during operation (see Figs. 7-9).

[0018] Due to the described configuration of the transformer 1 with the curved portion 6 at the outer wall 5 it is contributed to a reliable and efficient operation and to keep operation noise low.

[0019] It is pointed out, that the transformer 1 at least comprises one curved portion 6 at one associated outer wall 5. However, according to further embodiments the transformer 1 can comprise two or more curved portions 6 at a corresponding outer wall 5 (see Figs. 2-7). Moreover, the housing 2 of the transformer 1 is typically cuboid or cube-shaped substantially. Accordingly, the housing 2 comprises a top wall, a bottom wall and four outer walls 5. Each outer wall 5 can comprise one or more curved portions 6. For example, the four outer walls 5 can

comprise respective two curved portions 6 each shaped as a half cylinder as illustrated in the Figs. 1 and 2. Thus, the curved portions 6 can circumferentially surround the housing 2 and the inner components at an upper region 8 and a lower region 9 of the associated outer wall 5. Additionally, the top and/or the bottom wall can comprise one or more curved portions.

[0020] Further, the transformer 1 at least comprises one core 3 and one surrounding winding 4. However, alternatively the transformer 1 can comprise two or more cores 3 and/or windings 4, 10 (see Figs. 1-5). Further, a respective core 3 can be surrounded by two or more windings 4, 10 (see Figs. 6-9). The winding 4 can realize an inner winding configured to transform low voltage within a range of 100 V and 1000 kV, for example. The transformer 1 can comprise a further winding 10 that encloses or surrounds the core 3 and the inner winding 4 and hence realizing an outer winding configured to transform high voltage within a range of 1 kV and 2000 kV, for example.

[0021] The one or more curved portions 6 are preferably formed also in coordination with the associated one or more cores 3 and/or windings 4, 10. In particular, the curved portions 6 are formed at predetermined locations at a respective outer wall 5 where a relative large interaction between the penetrating magnetic field lines 7 and the housing 2 is to be expected depending on the characteristics of the transformer 1 or the inner components such as the core(s) 3 and/or winding(s) 4, 10.

[0022] The housing 2 can comprise respective elongated curved portions 6 (see Figs. 1-3) and/or respective single curved portions 6 (see Figs. 4 and 5). The curved portions 6 can all comprise the same or different shapes depending on the application and the characteristics of the transformer 1 and its inner components. A respective curved portion 6 can comprise a shape of a hemi-cylinder, a hemi-sphere or a semi-ellipsoid, for example. However, further shapes of the one or more curved portions 6, e.g. rectangular or cuboid shapes, can also contribute to a beneficial performance of the transformer 1.

[0023] The respective curved portion 6 can contribute to an reduced angle A of incidence of the magnetic field lines 7 that penetrates the outer wall 5 of the housing 2 compared to a flat outer surface wall (see Figs. 7 and 8).

[0024] It is a finding of the present disclosure that a stray magnetic flux interacts with a tank wall or outer wall 5 of the housing creating unwanted eddy currents. This eddy current causes losses and strongly influences the noise/vibration under loaded condition. The outer walls 5 with one or more curved portions 6 can alter the distribution of eddy currents and can beneficially reduce performance losses and noise generation of the transformer 1. Stray flux is inevitably produced in transformers during operation, but the specific configuration of the housing 2 and its walls can manipulate how it interacts with the outer walls 5. The curved portions 6 can be formed at separated strategic locations (see Figs. 6 and 7) or can be formed to realize an overall curved outer wall 5 (see

Figs.8 and 9).

[0025] A respective curved portion 6 has one or more given radii R of curvature realizing a wanted curved shape to change the stray flux interacting with the tank wall (see Fig. 6). Accordingly, in the case of at least two separated curved portions 6 at one outer wall 5 a distance D between the inner components, i.e. the core 3 and the winding(s) 4, 10, and the outer wall 5 in the region of the respective curved portion 6 is bigger than in a middle region between the curved portions 6 as illustrated in Fig. 6. Thus, the curved portions 6 realize an increased distance D that can cause a reduced interaction of stray magnetic flux with the tank wall.

[0026] A respective outer wall 5 can also comprise only one curved portion 6 which can form basically the whole outer wall 5 as indicated in the Fig. 8 and 9. As also shown in the Figs. 6 and 7, the Figs. 8 and 9 illustrate a schematic cross section view of one side of the core 3 or the transformer 1 according to a cross-section along a transverse or lateral direction B or C and a longitudinal direction L of the transformer 1 perpendicular to the lateral directions B and C.

[0027] According to Fig. 8, there are relative small flat portions of the outer wall 5 at the upper region 8 and at the lower region 9 and a predominantly large curved portion 6. A distance D between the inner components of the transformer 1 and the outer wall 5 in the middle region is bigger than in the upper region 8 and the lower region 9 (see also Fig. 9). Fig. 9 illustrates an overall curved portion 6 which form the entire outer wall 5. Such configurations can reduce the eddy current effect locally and hence can contribute to reduced performance losses and noise generation of the transformer 1 during operation.

[0028] The embodiment shown in the figures 1 to 9 as stated represent an exemplary embodiment of the improved transformer 1. Therefore, it does not constitute all embodiments. Actual arrangements may vary from the embodiment shown in the figures.

Reference signs

[0029]

- | | |
|----|---|
| 1 | transformer |
| 2 | housing of the transformer |
| 3 | core |
| 4 | winding |
| 5 | outer wall of the housing |
| 6 | curved portion of the outer wall |
| 7 | magnetic field lines |
| 8 | upper region of the outer wall |
| 9 | lower region of the outer wall |
| 10 | winding |
| A | angle of incidence |
| B | lateral direction of the transformer |
| C | lateral direction of the transformer |
| D | distance between a winding and the outer wall |

- | | |
|---|---|
| L | longitudinal direction of the transformer |
| R | radius of curvature of a curved portion |

Claims

1. A transformer (1), comprising:

- a core (3) and at least one winding (4, 10) for transforming current electromagnetically, wherein the at least one winding (4, 10) encloses the core (3) with respect to a lateral direction (B, C) of the transformer (1) and the core (3) and the winding (4, 10) are configured to cause a predetermined magnetic flux during operation of the transformer (1), and
- a housing (2) enclosing the core (3) and the winding (4, 10) with respect to the lateral direction (B, C) of the transformer (1) such that the winding (4, 10) is arranged between the core (3) and the housing (2), wherein the housing (2) comprises an outer wall (5) with at least one curved portion (6) that is formed in coordination with magnetic field lines (7) of the magnetic flux of the transformer (1) that arises during operation.

2. The transformer (1) according to claim 1, wherein the curved portion (6) comprises a predetermined radius of curvature (R) of 1 cm or greater.

3. The transformer (1) according to claim 1 or 2, wherein the curved portion (6) comprises a predetermined radius of curvature (R) of 10000 cm or smaller.

4. The transformer (1) according to any of the preceding claims, wherein the curved portion (6) comprises a radius of curvature (R) that is given at 1% up to 50% of a height of the outer wall (5).

5. The transformer (1) according to any of the preceding claims, wherein the outer wall (5) comprises two or more curved portions (6) spaced apart from each other, wherein one curved portion (6) is formed in an upper region (8) of the outer wall (5) and another curved portion (6) is formed in a lower region (9) of the outer wall (5) with respect to a longitudinal axis (L) of the transformer (1) across the lateral direction (B, C).

6. The transformer (1) according to claim 4, wherein the outer wall (5) is formed flat between the two curved portions (6) .

7. The transformer (1) according to any of the claims 1 to 3, wherein the outer wall (5) comprises an overall convex shape with respect to a longitudinal direction (L) of the transformer (1) across the lateral direction (B, C) such that a distance (D) between the winding

(4, 10) and a middle portion of the outer wall (5) is bigger than a distance (D) between the winding (4, 10) and an upper region (8) and a bottom region (9) of the outer wall (5).

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8. The transformer (1) according to any of the preceding claims, wherein the at least one curved portion (6) is formed circumferentially surrounding at the outer walls (5) of the housing (2).

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9. The transformer (1) according to any of the preceding claims, wherein the at least one curved portion (6) is formed with a hemi-spherical or semi-ellipsoidal shape.

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10. The transformer (1) according to any of the preceding claims, wherein the winding (4) is configured to transform low voltage within a range of 100 V and 1000 kV, and wherein the transformer (1) comprises a further winding (10) enclosing the core (3) configured to transform high voltage within a range of 1 kV and 2000 kV.

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Fig. 1

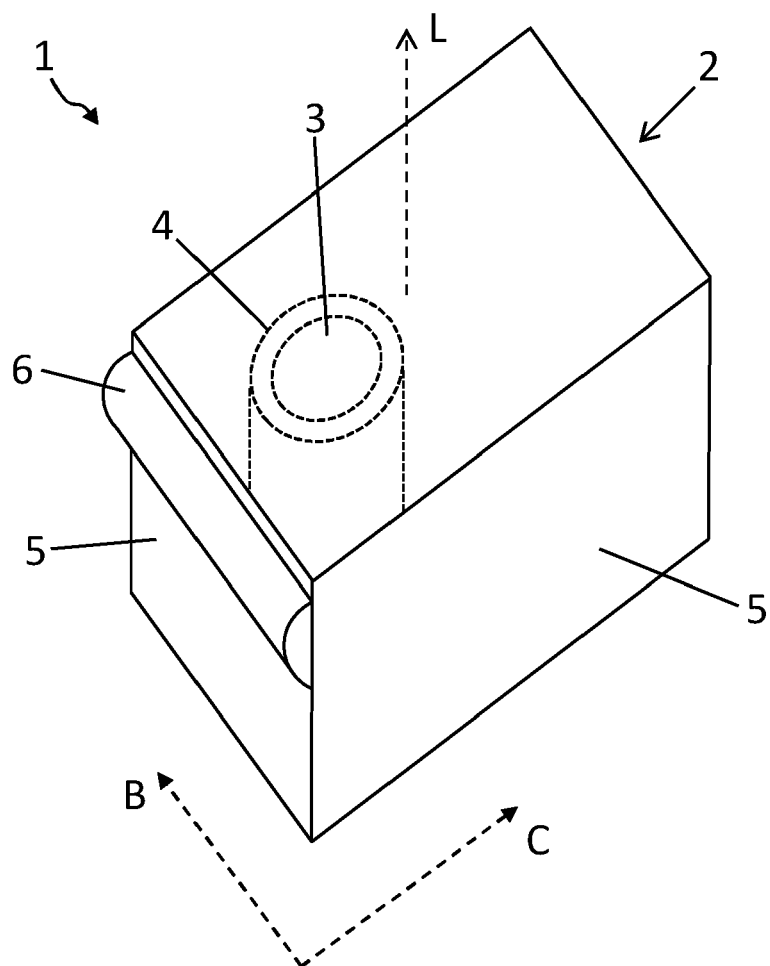


Fig. 2

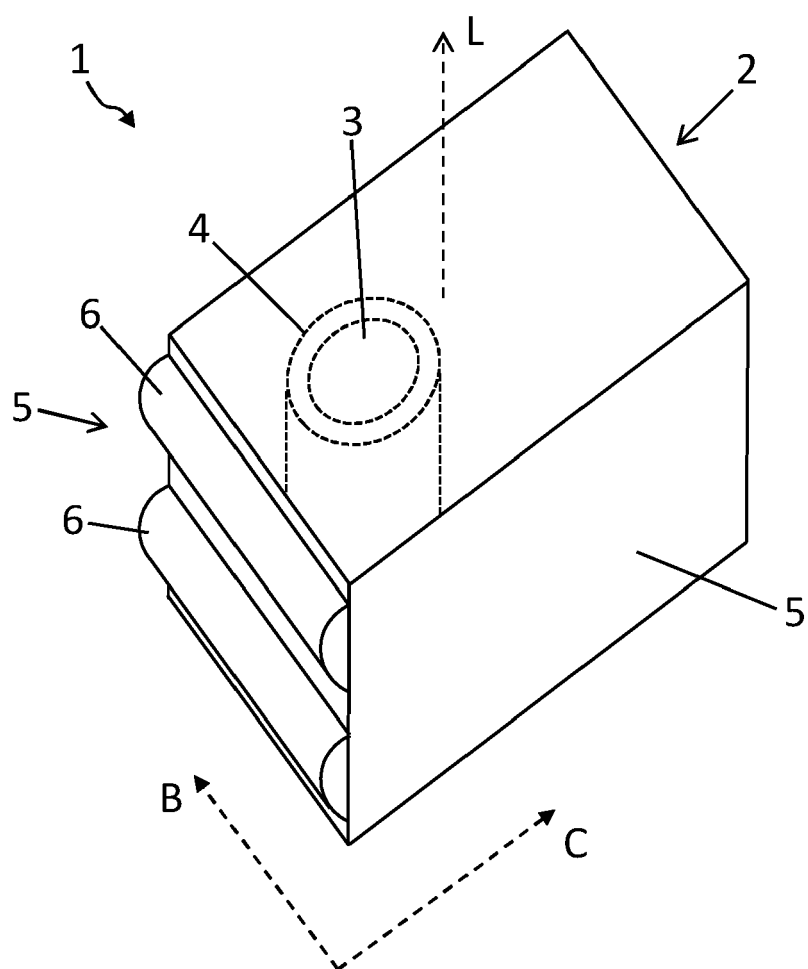


Fig. 3

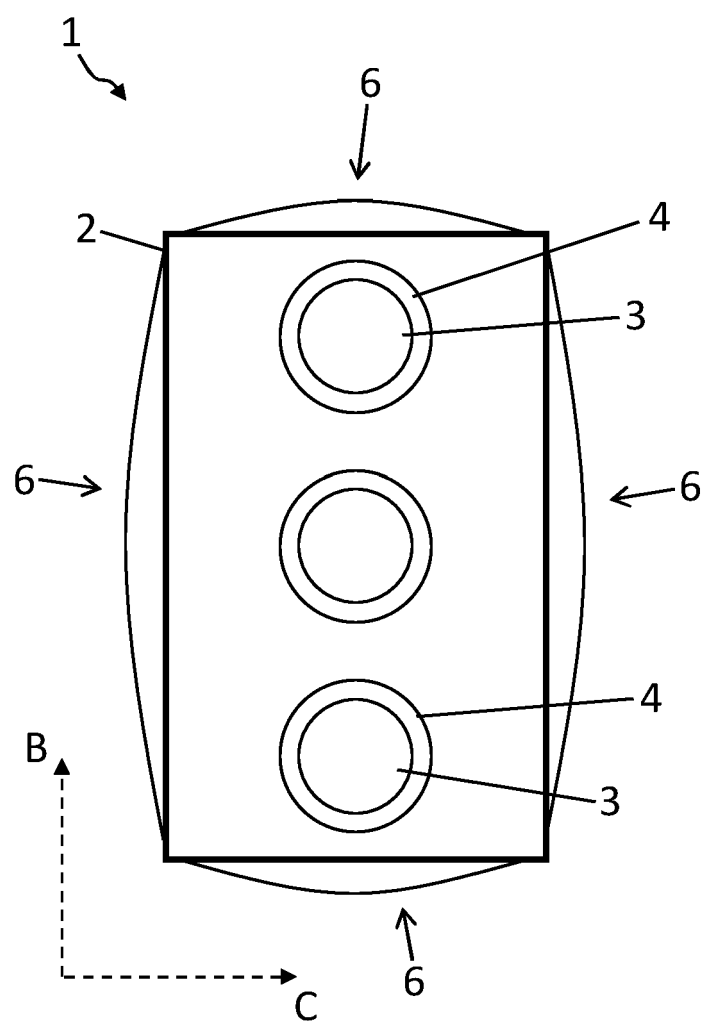


Fig. 4

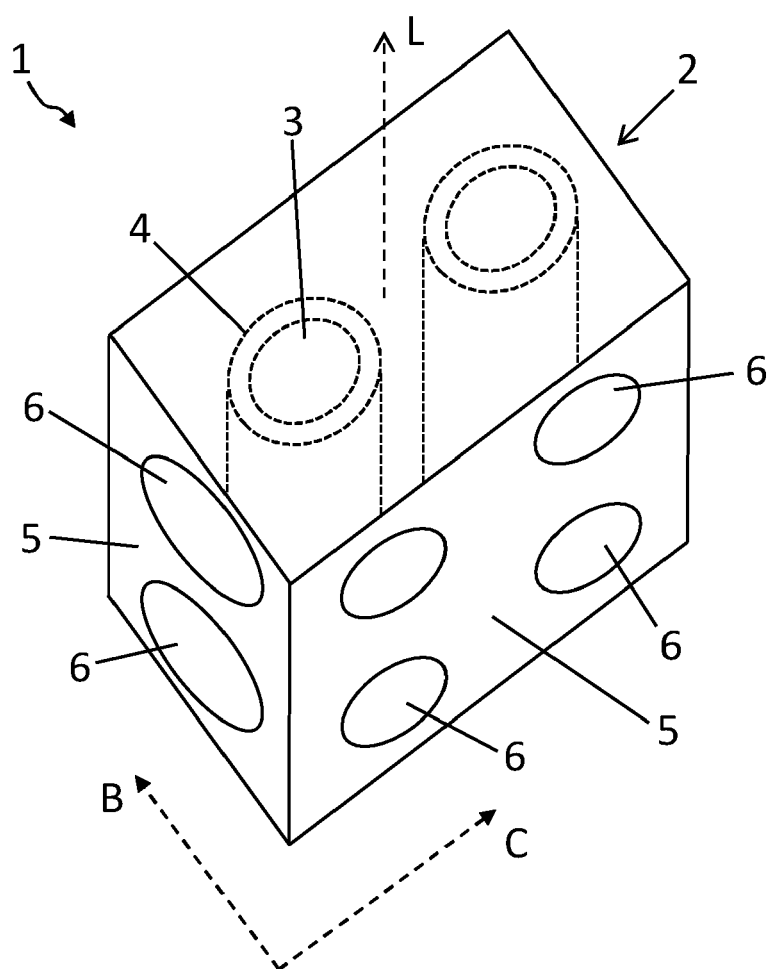


Fig. 5

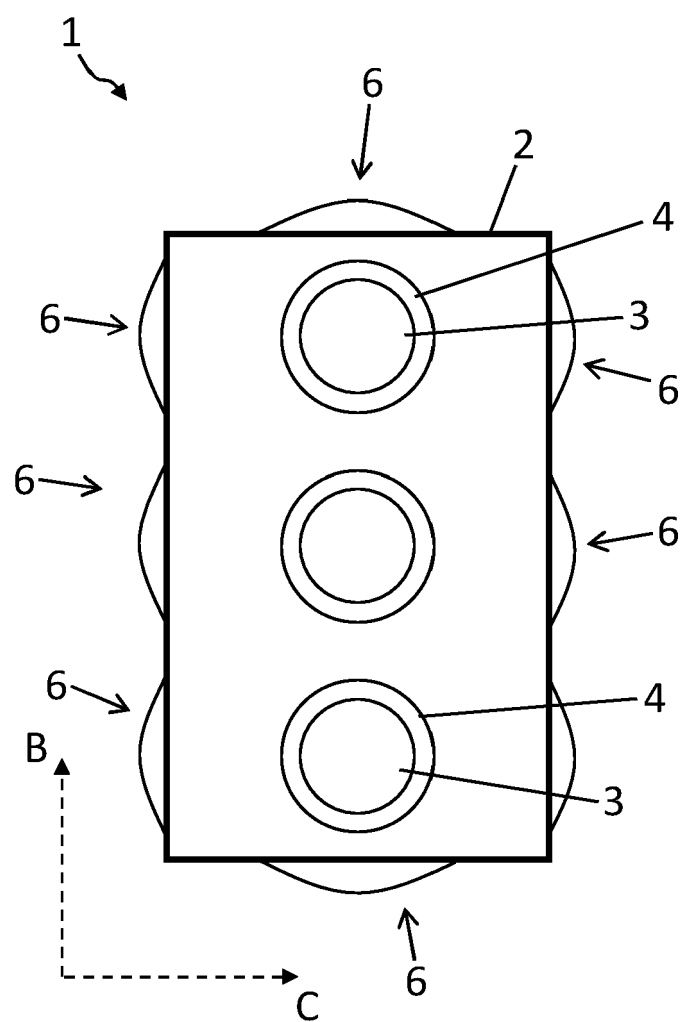


Fig. 6

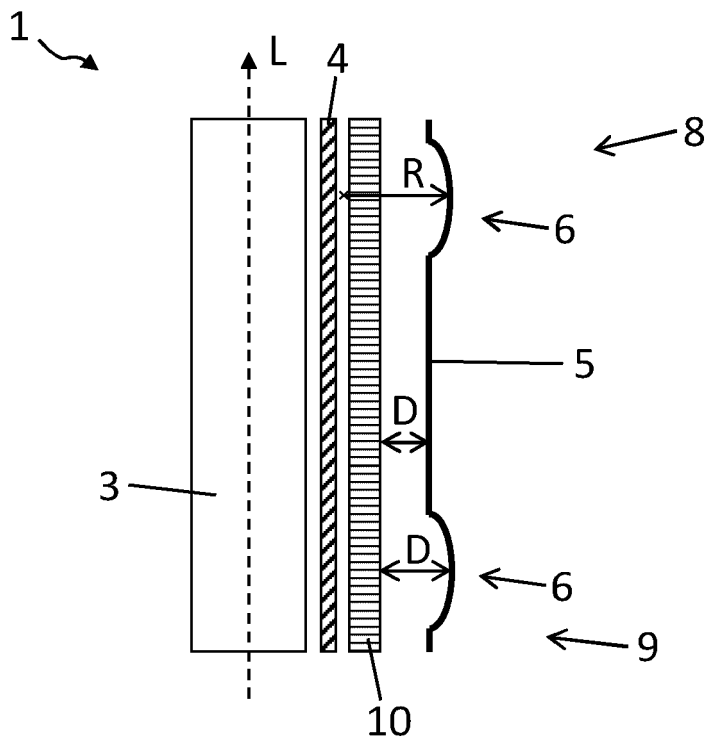


Fig. 7

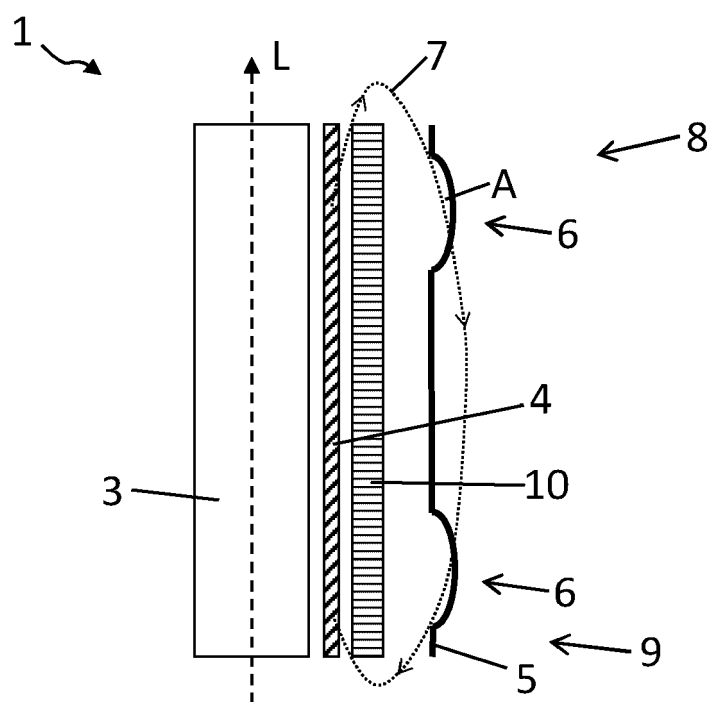


Fig. 8

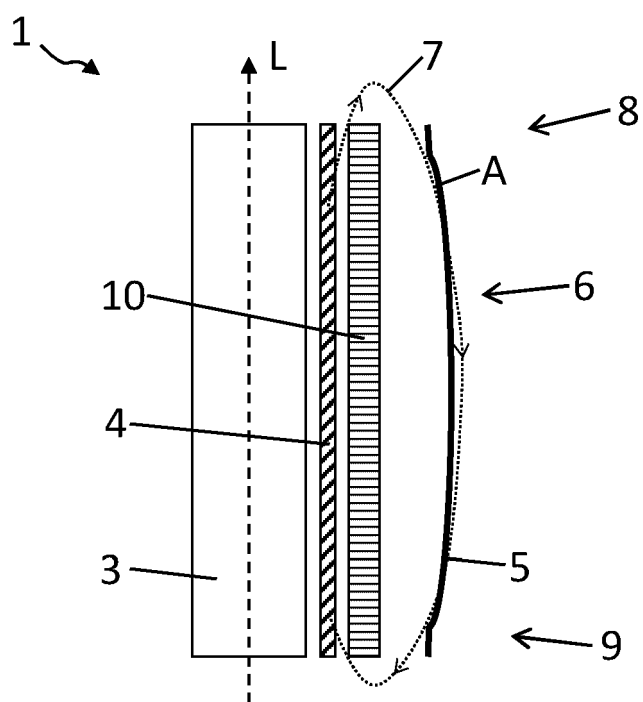
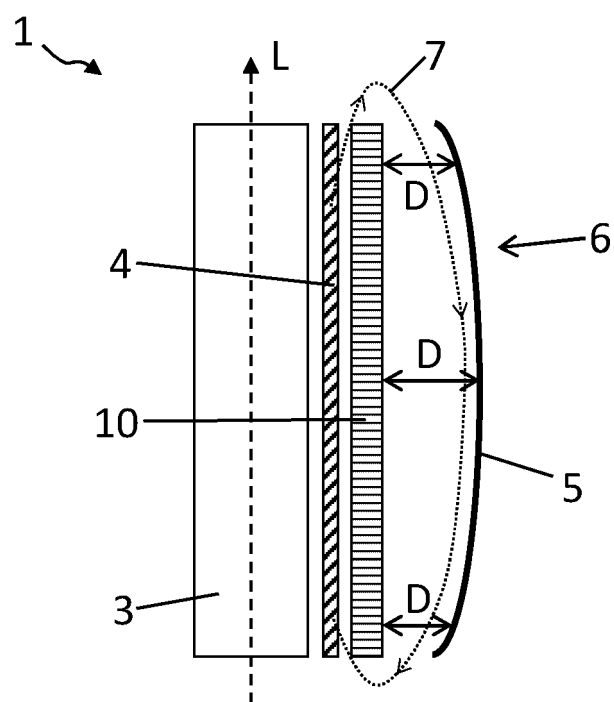


Fig. 9





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Application Number

EP 23 18 5228

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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 14 December 2023	Examiner Subke, Kai-Olaf
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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