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- **SANCHEZ, Ricardo**
77136 Ludvika (SE)
- **OLSSON, Kent**
772 50 Grängesberg (SE)
- **DAHLGREN, Johan**
771 94 Ludvika (SE)
- **SUNDQVIST, Anders**
771 35 Ludvika (SE)

(71) Applicant: **ABB Schweiz AG**
5400 Baden (CH)

(74) Representative: **Kransell & Wennborg KB**
P.O. Box 27834
115 93 Stockholm (SE)

(72) Inventors:
• **ANGER, Jan**
771 43 Ludvika (SE)

(54) **ELECTROMAGNETIC INDUCTION DEVICE**

(57) An electromagnetic induction device (1) comprising: an upper yoke (3), a lower yoke (5), a first core limb (7) extending between the upper yoke (3) and the lower yoke (5), wherein the upper yoke (3) includes: an upper laminated core, a pair of upper core clamps (3a) configured to clamp the upper laminated core (3c), and a first crossbar (15a) mechanically connecting the pair of upper core clamps (3a) with each other, the first crossbar (15a) extending between the pair of upper core clamps (3a) with at least a portion thereof aligned with the first core limb (7); wherein the lower yoke (5) includes: a lower laminated core, a pair of lower core clamps con-

figured to clamp the lower laminated core, and a second crossbar (15b) mechanically connecting the pair of lower core clamps, the second crossbar (15b) extending between the pair of lower core clamps with at least a portion thereof aligned with the first core limb (7); and a plurality of tie rods (13) extending between the upper yoke (3) and the lower yoke (5), the tie rods (13) being configured to apply forces onto the first crossbar (15a) via the upper core clamps (3a, 3b) and the second crossbar (15b) via the lower core clamps to fixate the first core limb (7) relative to the upper yoke (3) and the lower yoke (5).

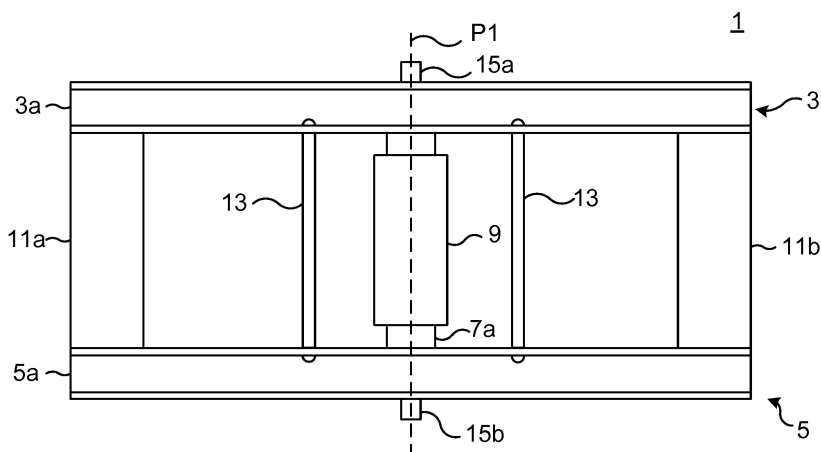


Fig. 1

Description

TECHNICAL FIELD

[0001] The present disclosure relates to electromagnetic induction devices, such as reactors and transformers, for power systems.

BACKGROUND

[0002] Electromagnetic induction devices such as reactors and transformers typically have a magnetic core comprising at least one phase limb and an upper and a lower yoke. The upper and lower yoke are usually connected by the phase limb. The two yokes may be made of a plurality of stacked metal sheets, which form a respective laminated core. The sheets may be held together by means of core clamps.

[0003] Three-phase reactors may have four tie rods which are used to apply pressure on four crossbars which press the yokes vertically in two locations, between the phase limbs. This causes significant bending stresses in the laminations of the yokes. The core steel laminations are very sensitive to mechanical stress. Bending stress is one important source of vibrations and noise in a reactor.

SUMMARY

[0004] A general object of the present disclosure is to provide an electromagnetic induction device which solves or at least mitigates the problem of the prior art.

[0005] There is hence provided an electromagnetic induction device comprising: an upper yoke, a lower yoke, a first core limb extending between the upper yoke and the lower yoke, wherein the upper yoke includes: an upper laminated core, a pair of upper core clamps configured to clamp the upper laminated core, and a first crossbar mechanically connecting the pair of upper core clamps with each other, the first crossbar extending between the pair of upper core clamps with at least a portion thereof aligned with the first core limb; wherein the lower yoke includes: a lower laminated core, a pair of lower core clamps configured to clamp the lower laminated core, and a second crossbar mechanically connecting the pair of lower core clamps, the second crossbar extending between the pair of lower core clamps with at least a portion thereof aligned with the first core limb; and a plurality of tie rods extending between the upper yoke and the lower yoke, the tie rods being configured to apply forces onto the first crossbar via the upper core clamps and the second crossbar via the lower core clamps to fixate the first core limb relative to the upper yoke and the lower yoke.

[0006] With this design yoke bending can be eliminated or at least reduced in the upper yoke and in the lower yoke. This may in particular be obtained because the vertical forces applied by the crossbars onto the upper

laminated core and the lower laminated core will essentially be counteracted by the position of the first core limb which is vertically aligned with the crossbars. The generation of vibrations and noise may thereby be reduced.

[0007] With at least a portion of the first crossbar/second crossbar being aligned with the first core limb is meant that after installation of the electromagnetic induction device on site the first crossbar is at least partly arranged aligned with and vertically above the first core limb and that the second crossbar is at least partly arranged aligned with and vertically below the first core limb.

[0008] The first crossbar may bear against the upper yoke and the second crossbar may bear against the lower yoke.

[0009] According to one embodiment a centre point of the first crossbar is aligned with a central longitudinal axis of the first core limb and wherein a centre point of the second crossbar is aligned with the central longitudinal axis of the first core limb.

[0010] According to one embodiment the first crossbar extends along a sagittal plane of the first core limb and the second crossbar extends along a sagittal plane of the first core limb.

[0011] According to one embodiment the central longitudinal plane of the first core limb is the median plane of the first core limb.

[0012] According to one embodiment the first crossbar has a central longitudinal axis that coincides with the sagittal plane of the first core limb.

[0013] According to one embodiment the second crossbar has a central longitudinal axis that coincides with the sagittal plane of the first core limb.

[0014] According to one embodiment each tie rod is mechanically attached to one of the upper core clamps of the pair of upper core clamps and to a corresponding one of the lower core clamps of the pair of lower core clamps.

[0015] According to one embodiment the plurality of tie rods comprise four tie rods arranged outside of the first core limb, two of which extend on a first side of the upper yoke and lower yoke and two of which extend on a second side of the upper yoke and the lower yoke.

[0016] According to one embodiment the electromagnetic induction device, comprises: a second core limb extending between the upper yoke and the lower yoke, a third crossbar mechanically connecting the pair of upper core clamps, the third crossbar extending between the pair of upper core clamps with at least a portion thereof aligned with the second core limb, and a fourth crossbar mechanically connecting the pair of lower core clamps, the fourth crossbar extending between the pair of lower core clamps with at least a portion thereof aligned with the second core limb.

[0017] According to one embodiment the third crossbar extends along a sagittal plane of the second core limb and the fourth crossbar extends along a sagittal plane of the second core limb.

[0018] According to one embodiment the sagittal plane of the second core limb is the median plane of the second core limb.

[0019] According to one embodiment the electromagnetic induction device comprises: a third core limb extending between the upper yoke and the lower yoke, a fifth crossbar mechanically connecting the pair of upper core clamps, the fifth crossbar extending between the pair of upper core clamps with at least a portion thereof aligned with the third core limb, and a sixth crossbar mechanically connecting the pair of lower core clamps, the sixth crossbar extending between the pair of lower core clamps with at least a portion thereof aligned with the third core limb.

[0020] According to one embodiment the fifth crossbar extends along a sagittal plane of the third core limb and the sixth crossbar extends along a sagittal plane of the third core limb.

[0021] According to one embodiment the sagittal plane of the third core limb is the median plane of the third core limb.

[0022] According to one embodiment the tie rods are arranged externally to the first core limb, the second core limb and the third core limb and extend between the upper yoke and the lower yoke.

[0023] According to one embodiment the tie rods extend in pairs adjacent to the first core limb and the second core limb, and the first core limb and the third core limb, in planes parallel with the sagittal plane of the first core limb.

[0024] One embodiment comprises a first side limb and a second side limb extending between the upper yoke and the lower yoke.

[0025] According to one embodiment the electromagnetic induction device is a reactor or a transformer.

[0026] According to one embodiment the electromagnetic induction device is a high voltage electromagnetic induction device.

[0027] If the electromagnetic induction device comprises one or more crossbars which are not aligned with any core limb, i.e. it/they is/are arranged laterally from the core limb(s), such a crossbars or crossbars must be vertically spaced apart from the upper yoke if it/they extends between the upper core clamps and from the lower yoke if it extends between the lower core clamps so that it/they do not apply vertical pressure directly on the corresponding yoke. Thus, the electromagnetic induction device only has crossbars which have a portion thereof aligned with a core limb, arranged in direct contact with a yoke.

[0028] Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, etc. are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, etc., unless explicitly stated otherwise.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The specific embodiments of the inventive concept will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 schematically shows a front view of an example of an electromagnetic induction device with its enclosure removed;

Fig. 2 schematically shows a top view of the electromagnetic induction device in Fig. 1;

Fig. 3 schematically shows a front view of another example of an electromagnetic induction device with its enclosure removed; and

Fig. 4 schematically depicts a top view of the electromagnetic induction device in Fig. 3.

DETAILED DESCRIPTION

[0030] The inventive concept will now be described more fully hereinafter with reference to the accompanying drawings, in which exemplifying embodiments are shown. The inventive concept may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the inventive concept to those skilled in the art. Like numbers refer to like elements throughout the description.

[0031] Figs 1 and 2 show an example of an electromagnetic induction device 1. The electromagnetic induction device 1 is shown without its enclosure. The electromagnetic induction device 1 may for example be a reactor or a transformer. The electromagnetic induction device 1 may for example be configured for medium voltage applications or high voltage applications. The exemplified electromagnetic induction device 1 is a single-phase electromagnetic induction device.

[0032] The electromagnetic induction device 1 comprises an upper yoke 3 and a lower yoke 5. The electromagnetic induction device 1 also includes a first core limb 7 extending between the upper yoke 3 and the lower yoke 5. The electromagnetic induction device 1 furthermore includes a first winding 9 arranged around the first core limb 7, a first and a second side limb 11a and 11b extending between the upper yoke 3 and the lower yoke 5 in parallel with and lateral to the first core limb 7, a plurality of tie rods 13, a first crossbar 15a and a second crossbar 15b.

[0033] The upper yoke 3 includes an upper laminated core 3c, shown in Fig. 2 and a pair of upper core clamps 3a and 3b. The upper laminated core 3c comprises a plurality of stacked metal sheets. The upper core clamps 3a and 3b are configured to clamp together the upper

laminated core 3c. In particular, the upper core clamps 3a and 3b are configured to clamp the metal sheets of the upper laminated core 3c together. The upper core clamps 3a and 3b are hence arranged at a respective long side of the upper laminated core 3c.

[0034] The first crossbar 15a extends across the upper laminated core 3c from one of the upper core clamps 3a to the other one of the upper core clamps 3b. The first crossbar 15a hence extends from one long side of the upper laminated core 3c to the other long side thereof. The first crossbar 15a may be mounted to the upper yoke 3, for example to each one of the upper core clamps 3a and 3b. The first crossbar 15a has a central longitudinal axis A1 shown in Fig. 2 which coincides with a sagittal plane P1 of the first core limb 7. The sagittal plane P1 is with respect to the front view of the electromagnetic induction device 1. The sagittal plane P1 must not necessarily be a centre plane, i.e. the median plane of the first core limb 7. The bend restriction effect is however increased the closer the sagittal plane P1 is to the median plane of the first core limb 7. Thus, according to one example, the sagittal plane P1 is the median plane of the first core limb 7, as shown in Fig. 1.

[0035] The lower yoke 5 has a similar configuration as the upper yoke 3. The lower yoke 5 includes a lower laminated core (not shown) and a pair of lower core clamps of which one lower core clamp 5a is shown in Fig. 1. The lower laminated core comprises a plurality of stacked metal sheets. The lower core clamps are configured to clamp together the lower laminated core. In particular, the lower core clamps are configured to clamp the metal sheets of the lower laminated core together. The lower core clamps are hence arranged at a respective long side of the lower laminated core.

[0036] The second crossbar 15b extends across the lower laminated core from one of the lower core clamps to the other one of the lower core clamps. The second crossbar 15b hence extends from one long side of the lower laminated core to the other long side thereof. The second crossbar 15b may be mounted to the lower yoke 5, for example to each one of the lower core clamps. The second crossbar 15b has a central longitudinal axis which coincides with the sagittal plane P1 of the first core limb 7.

[0037] The first crossbar 15a and the second crossbar 15b may be arranged parallel with each other, i.e. along the same sagittal plane P1, or alternatively, along different sagittal planes of the first core limb 7.

[0038] Each of the plurality of tie rods 13 extends between the upper yoke 3 and the lower yoke 5. The tie rods 13 are configured to hold the arrangement formed by the upper yoke 3, the lower yoke 5 and the first core limb 7 together. In particular, the tie rods 13 are configured to clamp the upper yoke 3 and the lower yoke 5 towards the first core limb 7. The force thus applied by the tie rods 13 is transferred to the first crossbar 15a via the upper core clamps 3a, 3b and to the second crossbar 15b via the lower core clamps which therefore due to their positions provide vertical forces onto the first core

limb 7.

[0039] The exemplary electromagnetic induction device 1 in Fig. 1 includes four tie rods 13. Two of the tie rods 13 are attached to one side of the upper yoke 3 and the lower yoke 5. The other two of the tie rods 13 are attached to the other side of the upper yoke 3 and the lower yoke 5. For example, two tie rods 13 may be attached to one of the upper core clamps 3a and the corresponding lower core clamp 5a. The other two tie rods 13 may be attached to the other one of the upper core clamps 3b and the corresponding lower core clamp.

[0040] The tie rods 13 are arranged externally/outside of the first core limb 7. Two tie rods 13 may be arranged in parallel with the first core limb 7, between the first core limb 7 and one of the side limbs 11a as seen in a side view. The other two tie rods 13 may be arranged in parallel with the first core limb 7, between the first core limb 7 and the other one of the side limbs 11b as seen in a side view.

[0041] Figs 3 and 4 show another example of an electromagnetic induction device. The electromagnetic induction device 1' is a multi-limb electromagnetic induction device. The exemplified electromagnetic induction device 1' is a three-phase electromagnetic induction device.

[0042] The electromagnetic induction device 1' is similar to the electromagnetic induction device 1. Electromagnetic induction device 1' however has a plurality of core limbs. In particular, electromagnetic induction device 1' additionally comprises a second core limb 17 arranged between the second side limb 11b and the first core limb 7, a second winding 19 arranged around the second core limb 17, a third core limb 21 arranged between the first side limb 11a and the first core limb 7, and a third winding 23 arranged around the third core limb 21. The electromagnetic induction device 1' furthermore comprises a third crossbar 25a, a fourth crossbar 25b, a fifth crossbar 27a, and a sixth crossbar 27b.

[0043] The third crossbar 25a extends across the upper laminated core 3c between the pair of upper core clamps 3a and 3b. The third crossbar 25a may be mounted to the upper yoke 3, for example to each one of the upper core clamps 3a and 3b. The third crossbar 25a has a central longitudinal axis A2 shown in Fig. 4 which coincides with a sagittal plane P2 of the second core limb 17. The sagittal plane P2 must not necessarily be a centre plane, i.e. the median plane of the second core limb 17. The bend restriction effect is however increased the closer the sagittal plane P2 is to the median plane of the second core limb 17. Hereto, preferably, the sagittal plane P2 is the median plane of the second core limb 17.

[0044] The fourth crossbar 25b extends across the lower laminated core from one of the lower core clamps to the other one of the lower core clamps. The fourth crossbar 25b may be mounted to the lower yoke 5, for example to each one of the lower core clamps. The fourth crossbar 25b has a central longitudinal axis which coincides with the sagittal plane P2 of the second core limb 17.

[0045] The fifth crossbar 27a extends across the upper laminated core 3c between the pair of upper core clamps 3a and 3b. The fifth crossbar 27a may be mounted to the upper yoke 3, for example to each one of the upper core clamps 3a and 3b. The fifth crossbar 27a has a central longitudinal axis A3 shown in Fig. 4 which coincides with a sagittal plane P3 of the third core limb 21. The sagittal plane P3 must not necessarily be a centre plane, i.e. the median plane of the second core limb 21. The bend restriction effect is however increased the closer the sagittal plane P3 is to the median plane of the third core limb 21. Hereto, preferably, the sagittal plane P3 is the median plane of the third core limb 21.

[0046] The sixth crossbar 27b extends across the lower laminated core from one of the lower core clamps to the other one of the lower core clamps. The sixth crossbar 27b may be mounted to the lower yoke 5, for example to each one of the lower core clamps. The sixth crossbar 27b has a central longitudinal axis which coincides with the sagittal plane P3 of the third core limb 17.

[0047] In general, the tie rods 13 are arranged externally to the first core limb 7, the second core limb 17 and the third core limb 21 and extend between the upper yoke 3 and the lower yoke 5. Two tie rods 13 may extend in parallel with and adjacent to the first core limb 7 and the second core limb 17 and two tie rods 13 may extend in parallel with and adjacent to the first core limb 7 and the third core limb 21. Two tie rods 13 may for example extend between the upper yoke 3 and the lower yoke 5 between the first core limb 7 and the second core limb 17 in a plane 29 parallel with the sagittal plane P1 of the first core limb 7. Two tie rods 13 may for example extend between the upper yoke 3 and the lower yoke 5 between the first core limb 7 and the third core limb 21 in a plane 31 parallel with the sagittal plane P1 of the first core limb 7.

[0048] The inventive concept has mainly been described above with reference to a few examples. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the inventive concept, as defined by the appended claims. There may for example be two crossbars extending between the pair of upper core limbs in a crossed-configuration, for example with the middle of the X-shape thus formed by the two crossbars being aligned with the central longitudinal axis of the first core limb. Similarly, there may according to one example be two crossbars extending between the pair of lower core limbs in a crossed-configuration, for example with the middle of the X-shape thus formed by the two crossbars being aligned with the central longitudinal axis of the first core limb

Claims

1. An electromagnetic induction device (1; 1') comprising:

- an upper yoke (3),
 - a lower yoke (5),
 - a first core limb (7) extending between the upper yoke (3) and the lower yoke (5),
- wherein the upper yoke (3) includes:

an upper laminated core (3c),
a pair of upper core clamps (3a, 3b) configured to clamp the upper laminated core (3c), and
a first crossbar (15a) mechanically connecting the pair of upper core clamps (3a, 3b) with each other, the first crossbar (15a) extending between the pair of upper core clamps (3a, 3b) with at least a portion thereof aligned with the first core limb (7);

wherein the lower yoke (5) includes:

a lower laminated core,
a pair of lower core clamps configured to clamp the lower laminated core, and
a second crossbar (15b) mechanically connecting the pair of lower core clamps, the second crossbar (15b) extending between the pair of lower core clamps with at least a portion thereof aligned with the first core limb (7); and

- a plurality of tie rods (13) extending between the upper yoke (3) and the lower yoke (5), the tie rods (13) being configured to apply forces onto the first crossbar (15a) via the upper core clamps (3a, 3b) and the second crossbar (15b) via the lower core clamps to fixate the first core limb (7) relative to the upper yoke (3) and the lower yoke (5).

2. The electromagnetic induction device (1; 1') as claimed in claim 1, wherein a centre point of the first crossbar (15a) is aligned with a central longitudinal axis of the first core limb (7) and wherein a centre point of the second crossbar (15b) is aligned with the central longitudinal axis of the first core limb (7).

3. The electromagnetic induction device (1; 1') as claimed in claim 1 or 2, wherein the first crossbar (15a) extends along a sagittal plane (P1) of the first core limb (7) and the second crossbar (15b) extends along a sagittal plane (P1) of the first core limb (7).

4. The electromagnetic induction device (1; 1') as claimed in claim 3, wherein the sagittal plane (P1) of the first core limb (7) is the median plane of the first core limb (7).

5. The electromagnetic induction (1; 1') device as claimed in claim 3 or 4, wherein the first crossbar

(15a) has a central longitudinal axis (A1) that coincides with the sagittal plane (P1) of the first core limb (7).

6. The electromagnetic induction device (1; 1') as claimed in any of claims 3-5, wherein the second crossbar (15b) has a central longitudinal axis that coincides with the sagittal plane (P1) of the first core limb (7). 5
7. The electromagnetic induction device (1; 1') as claimed in any of the preceding claims, wherein each tie rod (13) is mechanically attached to one of the upper core clamps (3a, 3b) of the pair of upper core clamps (3a, 3b) and to a corresponding one of the lower core clamps of the pair of lower core clamps. 10
8. The electromagnetic induction device (1; 1') as claimed in any of the preceding claims, wherein the plurality of tie rods (13) comprise four tie rods (13) arranged outside of the first core limb (7), two of which extend on a first side of the upper yoke (3) and lower yoke (5) and two of which extend on a second side of the upper yoke (3) and the lower yoke (5). 15 20
9. The electromagnetic induction device (1') as claimed in any of the preceding claims, comprising: 25
 - a second core limb (17) extending between the upper yoke (3) and the lower yoke (5), 30
 - a third crossbar (25a) mechanically connecting the pair of upper core clamps (3a, 3b), the third crossbar (25a) extending between the pair of upper core clamps (3a, 3b) with at least a portion thereof aligned with the second core limb (17), 35
 - and
 - a fourth crossbar (25b) mechanically connecting the pair of lower core clamps, the fourth crossbar (25b) extending between the pair of lower core clamps with at least a portion thereof aligned with the second core limb (17).. 40
10. The electromagnetic induction device (1') as claimed in claim 9, wherein the third crossbar (25a) extends along a sagittal plane (P2) of the second core limb (17) and the fourth crossbar (25b) extends along a sagittal plane (P2) of the second core limb (17). 45
11. The electromagnetic induction device (1') as claimed in claim 9, wherein the sagittal plane (P2) of the second core limb (17) is the median plane of the second core limb (17). 50
12. The electromagnetic induction device (1') as claimed in claim 7 or 8, comprising: 55
 - a third core limb (21) extending between the upper yoke (3) and the lower yoke (5),

a fifth crossbar (27a) mechanically connecting the pair of upper core clamps (3a, 3b), the fifth crossbar (27a) extending between the pair of upper core clamps (3a, 3b) with at least a portion thereof aligned with the third core limb (21), and a sixth crossbar (27b) mechanically connecting the pair of lower core clamps, the sixth crossbar (27b) extending between the pair of lower core clamps with at least a portion thereof aligned with the third core limb (17).

13. The electromagnetic induction device as claimed in claim 12, wherein the fifth crossbar (27a) extends along a sagittal plane (P3) of the third core limb (21) and the sixth crossbar (27b) extends along a sagittal plane (P3) of the third core limb (21).
14. The electromagnetic induction device (1') as claimed in claim 13, wherein the sagittal plane (P3) of the third core limb (21) is the median plane of the third core limb (21).
15. The electromagnetic induction device (1') as claimed in claim 13 or 14, wherein the tie rods (13) are arranged externally to the first core limb (7), the second core limb (17) and the third core limb (21) and extend between the upper yoke (3) and the lower yoke (5).

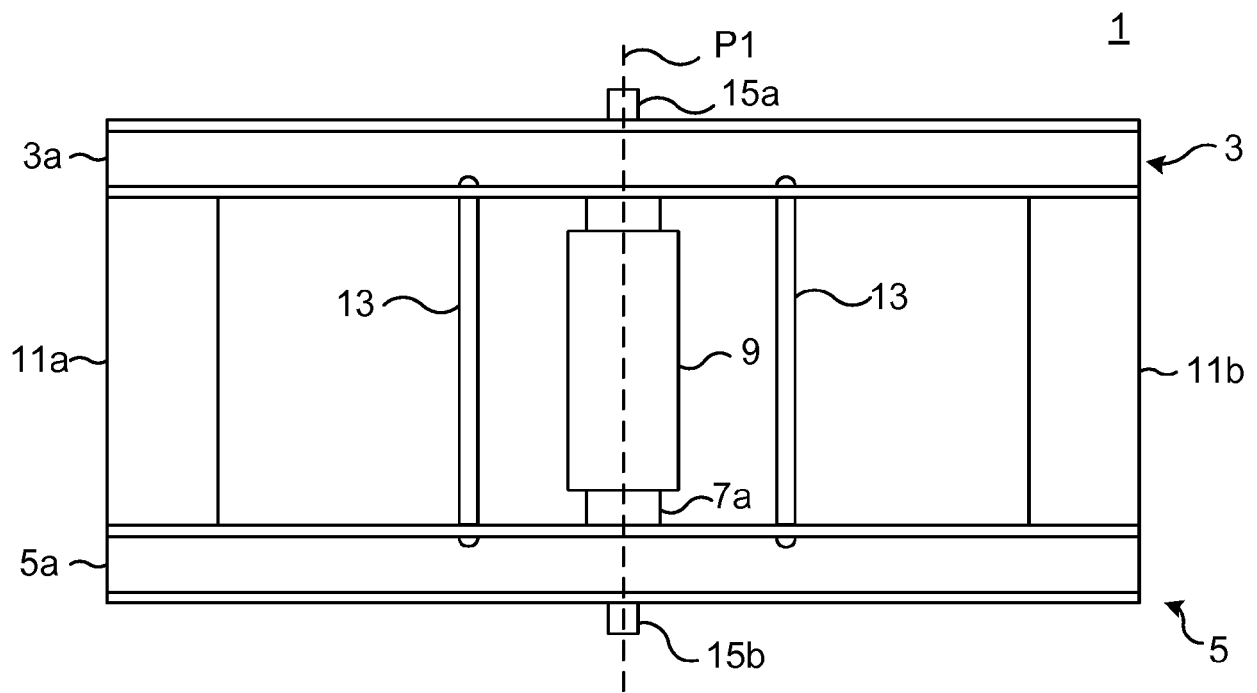


Fig. 1

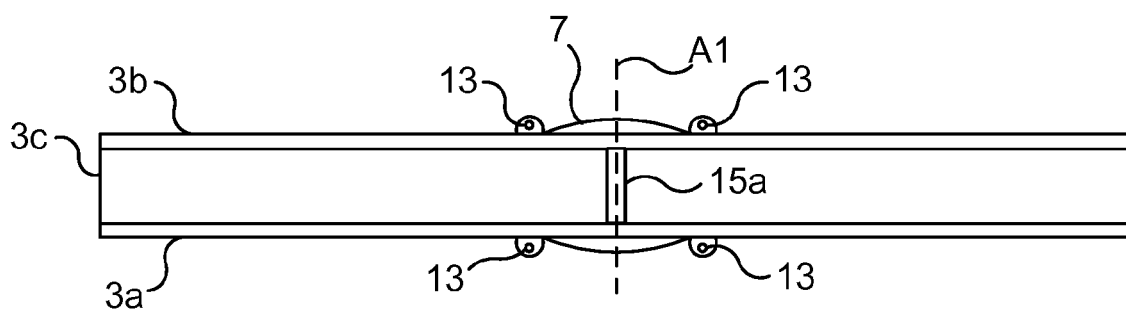


Fig. 2

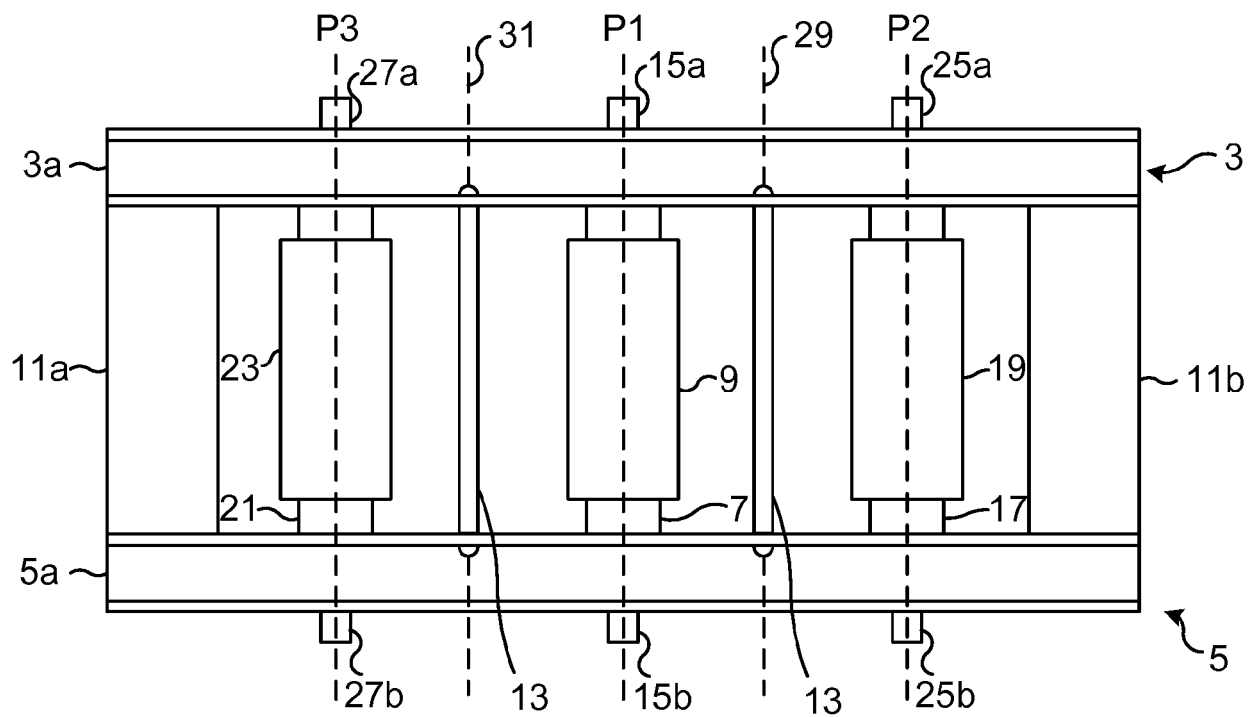


Fig. 3

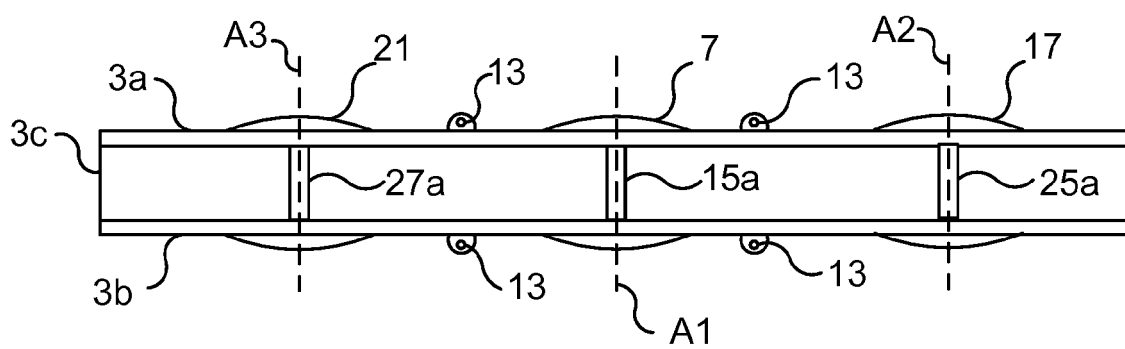


Fig. 4



EUROPEAN SEARCH REPORT

 Application Number
 EP 18 21 5372

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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 24 June 2019	Examiner Weisser, Wolfgang
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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