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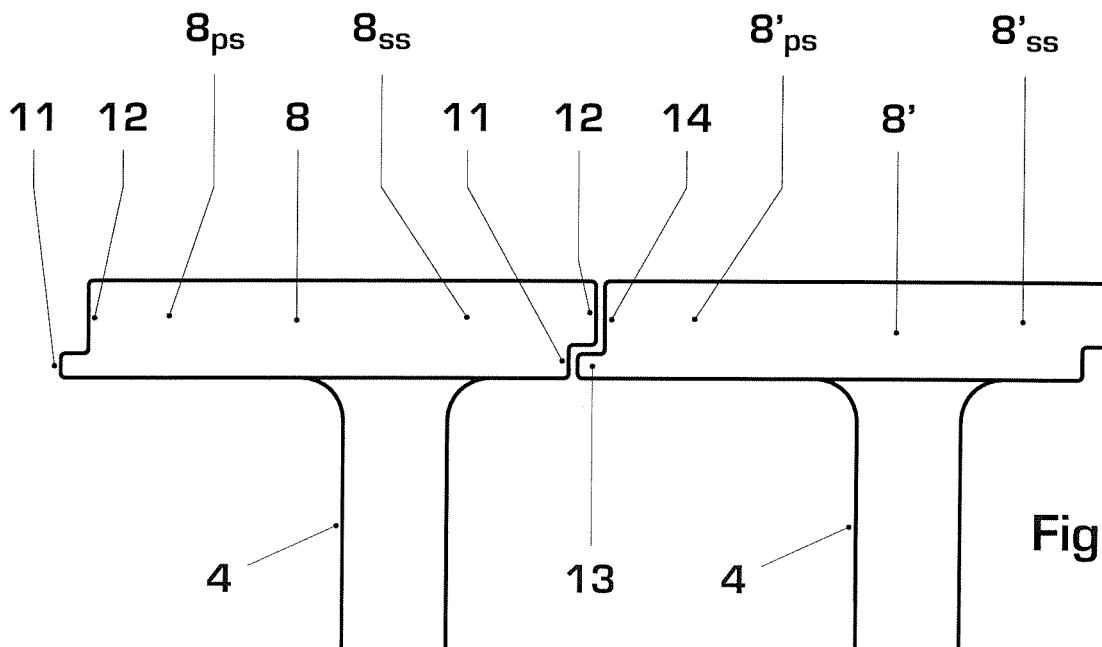
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(54) Turbine blade with shroud portions

(57) Rotating turbine blades in a blade row for a gas turbine have shrouds with shroud portions (8_{ss} , 8_{ps} , $8'_{ss}$, $8'_{ps}$) having different bending moments. The shroud portions with the smaller bending moment (8_{ss}) have edges with radially outer parts (12) that protrudes in circumfer-

ential direction over radially inner parts (13) of the shroud portion ($8'_{ps}$) of the adjacent blade that has a greater bending moment. The protruding shroud edge limits creep deformation of the shroud portion with the greater bending moment. The measure thus limits hot gas ingestion and prolongs turbine blade lifetime.

**Fig. 3****EP 1 840 333 A1**

Description

Technical Field

5 **[0001]** The invention pertains to rotating turbine blades in a blade row for use in a turbine such as a gas or steam turbine, the turbine blades having a shroud with a shape according to the shape of the shroud of an adjacent turbine blade in the blade row.

State of the Art

10 **[0002]** Shrouds on rotating turbine blades are intended to limit the leakage flows between the turbine blade tips and the casing.

In gas turbines, the blade shrouds are exposed to the hot gas flow. In order to prevent hot gas ingestion, that is a channeling of hot gas from the main gas flow channel into the space between the shroud and the casing, the shrouds have a shape that is matched to the shape of an adjacent shroud in a blade row and allowing an "interlocking" of the shrouds such that hot gas is prevented from reaching into the space between shroud and casing.

15 **[0003]** Two typical blades in a blade row with a shroud are shown in Figure 1. They comprises a blade airfoil 1 extending from a blade root 2 to a blade tip 3, from a leading edge 4 to trailing edge 5, and having a pressure side 6 and a suction side 7. The blade row rotates in the direction indicated by the arrow. The blade shroud 8 extends beyond the cross-sectional extent of the blade airfoil in the manner of a cantilever to the pressure side and the suction side of the blade. During operation of the blade in a gas turbine, due to centrifugal forces and high prevailing temperatures of the hot gas in the turbine, creep deformation of the cantilevered portions of the shroud can develop. The extent of the creep deformation is determined, among others, by the bending moment acting on the shroud, which is defined by the spatial extent of the shroud from the airfoil and the mass of the shroud. The extent of the shroud is greater on the pressure side than on the suction side. As a result, the bending moment and the resulting creep deformation is more pronounced on the pressure side than on the suction side and as such in an asymmetric deformation and loading of the shrouds.

25 **[0004]** An asymmetric creep deformation effects a mismatch in the radial direction of the shroud edges of adjacent blades in the blade row. The mismatch in turn allows an opening for hot gas in the turbine to flow into the spaces between the shrouds and the casing and to cause serious overheating and shortening of the operational lifetime of the blades.

30 **[0005]** A measure known in the state of the art to reduce creep deformation in turbine blade shrouds is the reduction of mass of a knife-edge on the shroud, as disclosed for example in DE 10 2004 025 321.

[0006] JP 7233703 discloses a gas turbine blade shroud having fillets attached to the lower and upper surface of the shroud in order to limit creep deformation.

35 **[0007]** EP 0 928 880 discloses a tip shroud for a moving blade in a gas turbine comprising grooves on the shroud faces and cooling guide covers. The measures allow increased cooling of high stress regions of the shroud and an increase in creep lifetime.

Summary of the Invention

40 **[0008]** It is the object of the invention to provide rotating turbine blades with shrouds in a blade row, which have an increased operational lifetime or are operational at an increased gas temperature. In particular, the rotating turbine blades shall develop a reduced creep deformation such that hot gas ingestion is prevented.

[0009] Rotating blades in a blade row for a gas turbine each comprise an airfoil having a pressure side and a suction side. A shroud attached to the tip of the blade has portions that extend over the suction and pressure side of the blade, where the edge of the shroud portion on the suction side of each blade faces the edge of the shroud portion on the pressure side of the adjacent blade in the blade row. The shroud portion on the suction side and pressure side of the blade each have a bending moment. According to the invention, for each blade in the blade row, the shroud portion having the smaller bending moment comprises at its edge facing the adjacent blade a radially outer part that extends in circumferential direction beyond a radially inner part of that shroud portion, and the shroud portion having the greater bending moment comprises at its edge facing the adjacent blade a radially inner part that extends beyond a radially outer part of that shroud portion. The radially outer and inner parts of each shroud portion of adjacent blades in the blade row are shaped such that the radially outer parts of the portions with the smaller bending moments protrude over the radially inner parts of the shroud portion with the greater bending moments of the adjacent blade.

50 **[0010]** Typically, the shroud portion having the smaller bending moment is the shroud portion on the suction side, and the shroud portion having the greater bending moment is the shroud portion on the pressure side. In a first embodiment of the invention therefore, the shroud portion on the suction side of each blade shroud comprises a radially outer part that protrudes beyond a radially inner part of that shroud. In particular, the radially outer part of the suction side portion protrudes over the radially inner part of the pressure side shroud portion of the adjacent blade in the blade row.

[0011] The shrouds have portions shaped such that there is an overlap of adjacent shrouds. The shroud portion on the suction side of a blade, having the smaller bending moment, overlaps on its radially outer side the shroud portion on the pressure side of the adjacent blade, having the greater bending moment. This effects that the shroud portion on the pressure side of a blade, which has the greater bending moment and normally develops the larger creep deformation, is now prevented from deforming in the radially outward direction by the overlapping portion on the suction side of the adjacent shroud. The shroud portion on the suction side of the blades thus supports the shroud portion on the pressure of the blade shrouds. As a result, the loading is spread more evenly over the blades in the blade row. The shroud portions having the smaller bending moments support the shroud portions having the larger bending moments.

[0012] The invention is described above for typically turbine blades with a shroud having a greater bending moment on the pressure side of the blade and to a measure to reduce the creep deformation of the shroud on that pressure side. In principle, it is also possible that a turbine blade has a shroud with a greater bending moment on the suction side of the blade. The measure according to the invention of overlapping shroud portions of adjacent blades is equally well applicable to blades having a greater bending moment on the pressure side as to blades having a greater bending moment on the suction side. The scope of the invention therefore includes the measure for both types of shrouded blades.

[0013] In a first embodiment of the invention, the radially outer part and radially inner part of the shroud edges are shaped in a step-like manner. That is, beginning at the radially inner surface of the shroud, the shroud edge first extends over the first portion in the radial direction, then extends for example at right angle to the first portion in the circumferential direction, and finally extends again in the radial direction to the radially outer surface of the shroud. In other examples of this embodiment, the step-like shape is realised with a angles that are approximately a right angle.

[0014] In a second embodiment of the invention, the shroud edges are slanted compared to the radial direction where the slant angles of adjacent blade shrouds are matched. The radially outer part of a shroud portion again overlaps the radially inner part of the shroud portion of the adjacent blade.

[0015] In a third embodiment of the invention, which is in a sense a combination of the shapes of the first and second embodiment, the shroud edges have a first, radially inner part and a second radially outer part. The first part extends from the radially inner surface of the shroud in the radial direction, and the second part extends from the first part at an angle to the radially outer surface of the shroud.

[0016] The shroud edges comprise the supporting structure with protruding portions according to the invention at least in the thicker regions of the shroud. In one embodiment of the invention the supporting structure extends over the region of the knife-edges. In these regions of the shroud the supporting structures are also most effective because the bending moments are typically the largest.

[0017] In another embodiment of the invention, blade shrouds comprise the supporting overlapping structure in the knife-edge regions as well as in the center regions of the shroud. This embodiment however is conditional on a sufficient thickness of the shroud.

Brief Description of the Figures

[0018]

Figure shows two adjacent rotating blades in a blade row, each comprising a shroud,
figure 2 shows an example of creep deformation on typical rotating blade,
figure 3 shows in a cross-section in the circumferential direction of the turbine blade shrouds the first embodiment of the shrouded turbine blade according to the invention,
figure 4 shows the second embodiment of the shrouded turbine blade according to the invention,
figure 5 shows the third embodiment of the shrouded turbine blade according to the invention.

Detailed Description of the Invention

[0019] The blades in a blade row for a gas turbine with shrouds shown in figure 1 are described in the section on state of the art.

[0020] Figure 2 shows in solid lines the same two blades for a gas turbine as in figure 1. The broken lines show the blades after a certain time in operation. The shroud portions on the pressure side of the blades have developed creep deformation due to centrifugal forces and the high temperatures in the gas turbine. The edges of the shrouds have deformed by an amount indicated by Δ . Such deformations are most pronounced where the shroud experiences the greatest bending moment, that it where it extends the most away from the airfoil and/or where it has its greatest mass. In the example shown, the greatest deformations occur at the corner on the pressure side of the shroud where the deformation is indicated by Δ .

[0021] Figure 3 shows a cross-section of the knife-edges 25 of the adjacent blade shrouds in a blade row of figure 1. The knife-edges extend in the circumferential direction on the leading edge side of the blade shroud. The blade shrouds

each have a portion on their suction side and a portion on the pressure side, where the portion on suction has a smaller bending moment compared to the portion on the pressure side. The cross-section shows in particular the supporting, overlapping structure of the knife-edges. The knife-edge of a first blade shroud 8 has at its edge on the suction side portion 8_{ss} facing the adjacent blade shroud 8' a first, radially inner part 11 and a second, radially outer part 12, which extends in circumferential direction beyond the first part 11. The knife-edge of the adjacent blade shroud 8' has at its edge on the pressure side portion $8'_{ps}$ of the adjacent blade shroud 8' has a radially inner part 13 that extends beyond a radially outer part 14. The parts 11-14 are shaped and dimensioned such that the shapes of the adjacent shroud edges are matched to one another and an overlap of the step-like features is established. The overlapping edge of the suction side portion 8_{ss} provides a support of the pressure side portion $8'_{ps}$ and prevents a deformation of part 13 in the radial direction.

[0022] Figure 4 shows a variant of the overlapping, supporting structure. Instead of a step-like shape the edges are slanted at angle α with respect to the inner and outer surface of the shroud. The edge on the suction side portion of the shroud essentially has a radially inner part 15 and a radially outer part 16 that extends in circumferential direction beyond the radially inner part 15. Similarly, the edge of the shroud on the pressure side of the adjacent shroud has a radially inner part 17 and a radially outer part 18, where the radially inner part 17 protrudes beyond the radially outer part 18. The edges are shaped such that their shapes are matched to that of the adjacent edge. The edge of the suction side portion 8_{ss} having the smaller bending moment overlaps the edge of the pressure side portion $8'_{ps}$ of the adjacent shroud such that a creep deformation in the radial direction of the pressure side portion $8'_{ps}$ is prevented by the supporting suction side portion 8_{ss} . The slant angle is dimensioned in order according to the prevailing bending moments and to provide a sufficient support. Values for the slant angle α are chosen in view of two criteria. On one hand, the angle is minimized in order to achieve greatest possible overlap and thus maximised prevention of the creep deformation in the radial direction of the shroud portion having the greater bending moment. On the other hand, the angle is maximized in order that the shroud portion with the smaller bending moment does not extend too far in the circumferential direction and develop too great a bending moment itself. Suitable angles may for example be in a range less than 80° , preferably in a range between 30° and 60° . A particularly suitable angle may be approximately 40° .

[0023] Figure 5 shows a further variant of the overlapping, supporting structure. The edges of the shrouds have in this case first parts 19, 20 extending radially from the inner surface of the shroud and slanted parts 21-24, extending from the first part to the outer surface of the shroud at a slant angle α to the outer surface of the shroud. The slanted parts have radially inner parts 21, 23 and radially outer parts 22, 24. The edges of adjacent shrouds again are matched in shape to one another for the same purpose as mentioned in connection with figure 3 and 4. The radially extending parts 19, 20 are spaced at a distance a for tolerance purposes. The distance a is chosen large enough in order to provide the necessary space for installation of the blades on the rotor, in particular the last blade of the blade row. It must however also be chosen small enough to prevent a gap between adjacent blade shrouds during operation when the thermal expansion and an untwisting of the blades occurs.

[0024] For each of the variants shown in figures 3-5 the overlapping and supporting contour of the shroud edges extends according over the region of a knife-edge 25 (as indicated in figure 1 and 2) of the shroud.

In a further embodiment of the invention the overlapping edges can be realised over the entire length of the edge facing the adjacent blade shroud. This is possible provided the thickness of the shroud in its center region is sufficient regarding manufacturability and strength considerations. Such a shroud is applicable for example to blades for steam turbines.

Reference terms used in figures

[0025]

1	blade airfoil
2	blade root
3	blade tip
4	leading edge
5	trailing edge
6	pressure side
7	suction side
8	blade shroud
8'	adjacent blade shroud in blade row
8_{ss} , 8_{ps} , $8'_{ss}$, $8'_{ps}$	suction side and pressure side portions of blade and adjacent blade
9	blade shroud on pressure side in original shape
10	blade shroud on pressure side in deformed shape
11-24	shroud edge parts for supporting structure
25	knife-edge of the shroud

Δ	radial deformation of blade portion on pressure side
α	slant angle of supporting structure
a	tolerance spacing between adjacent blade shroud in a blade row

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Claims

1. Rotating blades in a blade row for a turbine comprise an airfoil (1) having a pressure side (6) and a suction side (7) and a shroud (8) attached to a blade tip (3) each having a first shroud portion extending (8_{ss} , $8'_{ss}$) over the suction side (7) and a second shroud portion extending (8_{ps} , $8'_{ps}$) over the pressure side (6) of the blade, where one of the shroud portions has a bending moment greater than the other shroud portion, and the edges of each shroud portion (8_{ss} , 8_{ps} , $8'_{ss}$, $8'_{ps}$) face the edges of the shroud portions of an adjacent blade in the blade row
characterised in that
for each blade in the blade row, the shroud portion (8_{ss} , $8'_{ss}$) having a smaller bending moment comprises at its edge facing the adjacent blade a radially outer part (12, 16, 22) that extends in circumferential direction beyond a radially inner part (11, 15, 21) of that shroud portion, and the shroud portion (8_{ps} , $8'_{ps}$) having the greater bending moment comprises at its edge facing the adjacent blade a radially inner part (13, 17, 23) that extends in circumferential direction beyond a radially outer part (14, 18, 24) of that shroud portion (8_{ps} , $8'_{ps}$), and the radially outer parts (12, 16, 22) of each shroud portion (8_{ss} , $8'_{ss}$) having a smaller bending moment protrude over the radially inner parts (13, 17, 23) of the shroud portion (8_{ps} , $8'_{ps}$) of the adjacent blade with the greater bending moment.
2. Rotating turbine blades in a blade row according to claim 1
characterised in that
the suction side portion (8_{ss} , $8'_{ss}$) of each blade shroud has the smaller bending moment and the pressure side portion (8_{ps} , $8'_{ps}$) of each blade shroud has the greater bending moment.
3. Rotating turbine blades in a blade row according to claim 1
characterised in that
the pressure side portion of each blade shroud has the smaller bending moment and the suction side portion of each blade shroud has the greater bending moment.
4. Rotating turbine blades in a blade row according to one of the claims 1-3
characterised in that
the radially inner and outer parts (11-14) of the edges of the shroud portions are shaped in a step.
5. Rotating turbine blades in a blade row according to one of the claims 1-3
characterised in that
the edges of the shroud portions (15-18, 21-24) facing the adjacent blade shroud extend at a slant angle (α) with respect to the inner and outer surface of the shroud.
6. Rotating turbine blades in a blade row according to one of the claims 1-3
characterised in that
the edges of the shroud facing the adjacent blade comprises a first portion (19, 20) extending radially from the inner surface of the shroud and a second portion (21-24) extending from the first portion (19, 20) and at a slant angle (α) to the outer surface of the shroud.
7. Rotating turbine blades in a blade row according to claim 5 or 6
characterised in that
the slant angle (α) is less than 80°.
8. Rotating turbine blades in a blade row according to claim 5 or 6
characterised in that
the slant angle (α) is less in a range from 30° to 60°.
9. Rotating turbine blades in a blade row according to claim 5 or 6
characterised in that

the slant angle (α) is approximately 40° .

10. Rotating turbine blades in a blade row according to one of the foregoing claims

characterised in that

5 the radially outer parts (12, 16, 23) of each shroud portion (8_{ss} , $8'_{ss}$) having a smaller bending moment, the radially outer parts protruding over the radially inner parts (13, 17, 22) of the shroud portion (8_{ps} , $8'_{ps}$) of the adjacent blade with the greater bending moment extend over the region of knife-edges (25) on the shroud.

11. Rotating turbine blades in a blade row according to one of the foregoing claims

characterised in that

10 the radially outer parts (12, 16, 22) of each shroud portion (8_{ss} , $8'_{ss}$) having a smaller bending moment, the radially outer parts protruding over the radially inner parts (13, 17, 23) of the shroud portion (8_{ps} , $8'_{ps}$) of the adjacent blade with the greater bending moment extend over the entire length of the edge of the shroud.

12. Rotating turbine blades in a blade row according to one of the foregoing claims

characterised in that

15 the turbine is a gas turbine or a steam turbine.

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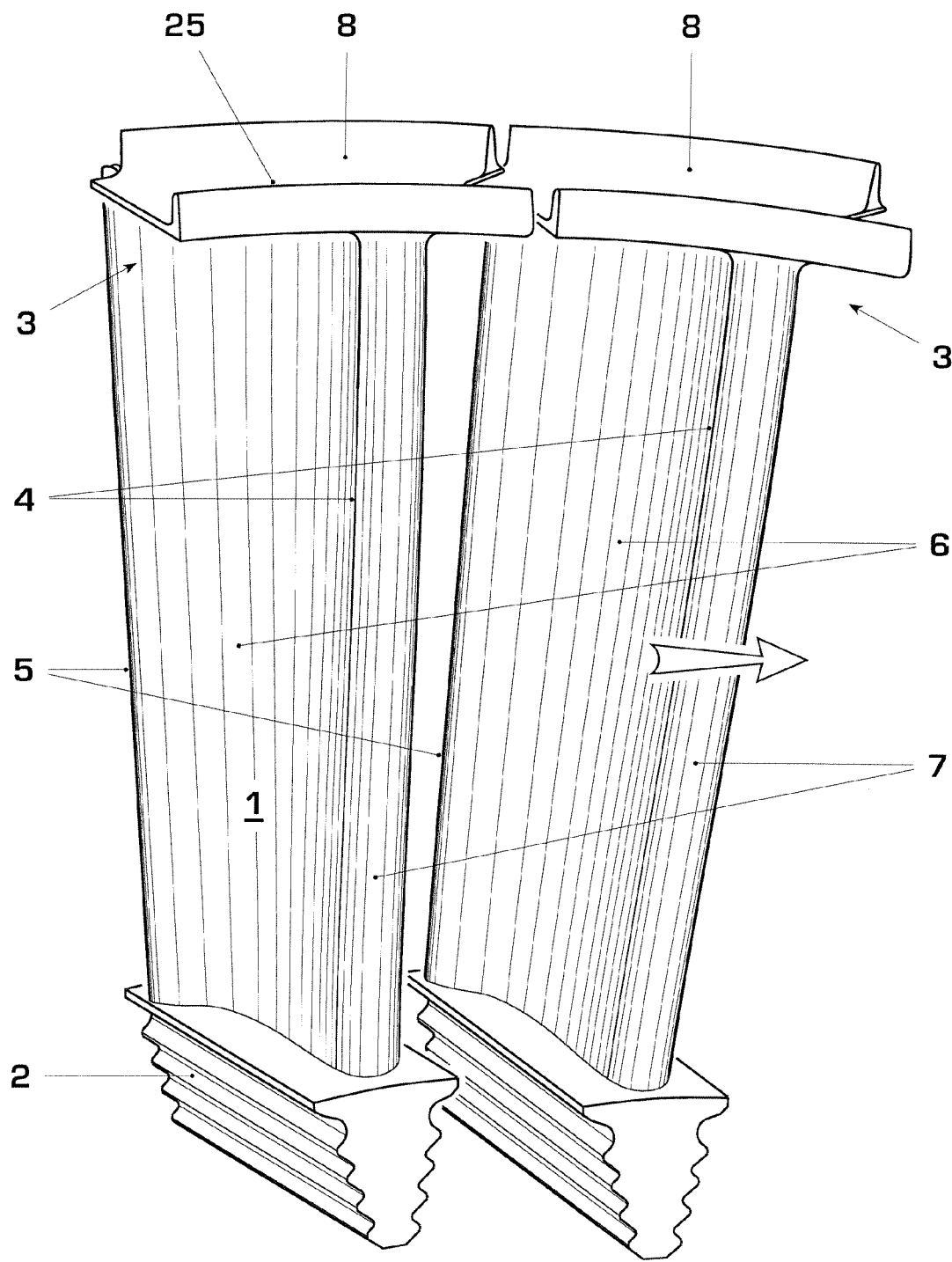
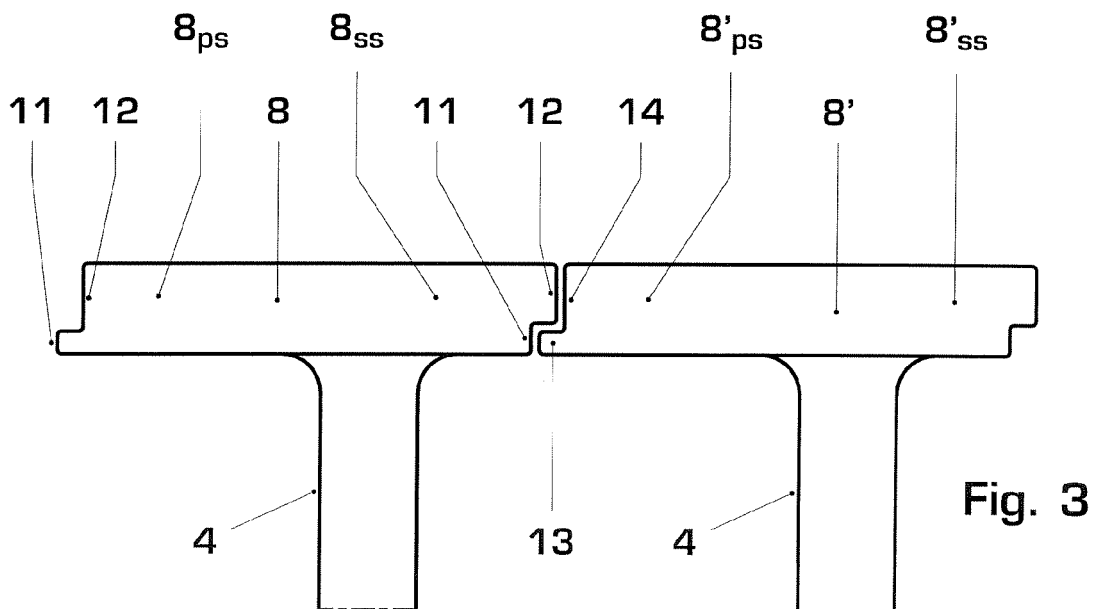
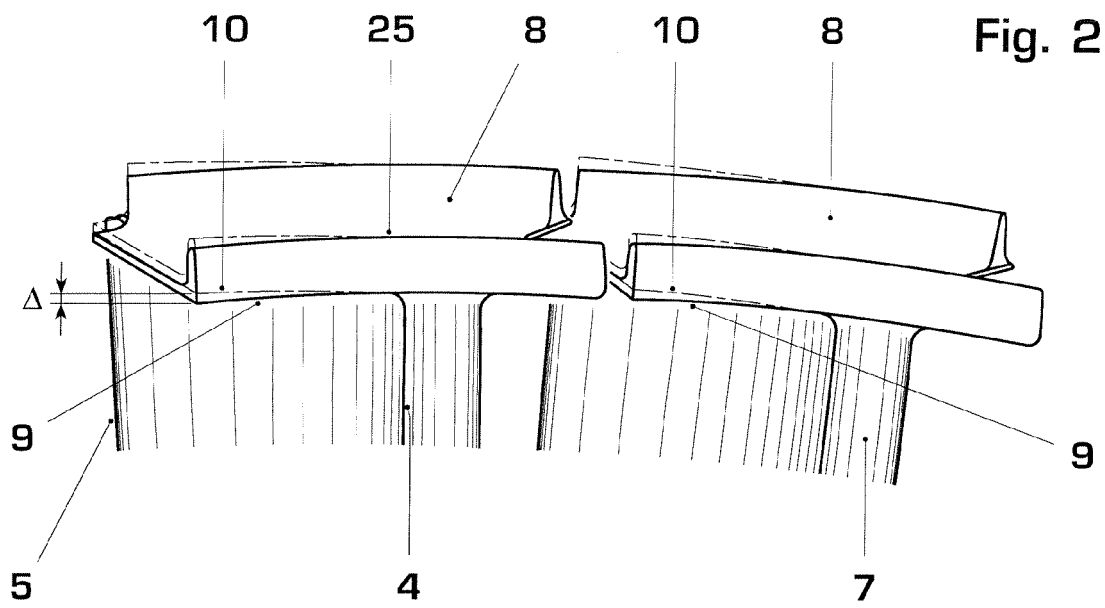
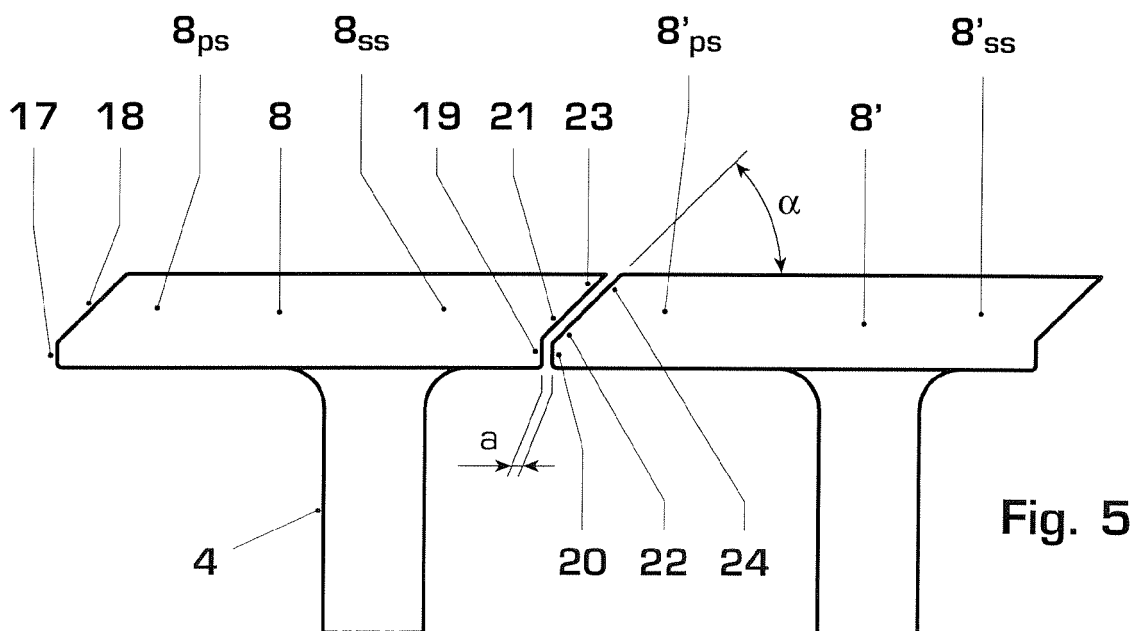
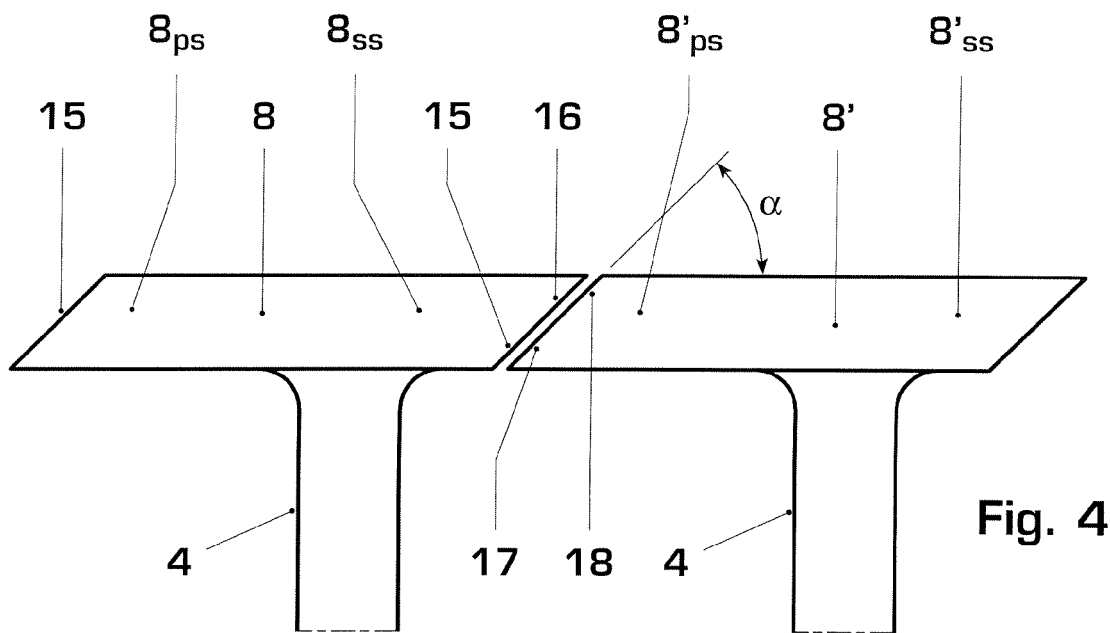


Fig. 1







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