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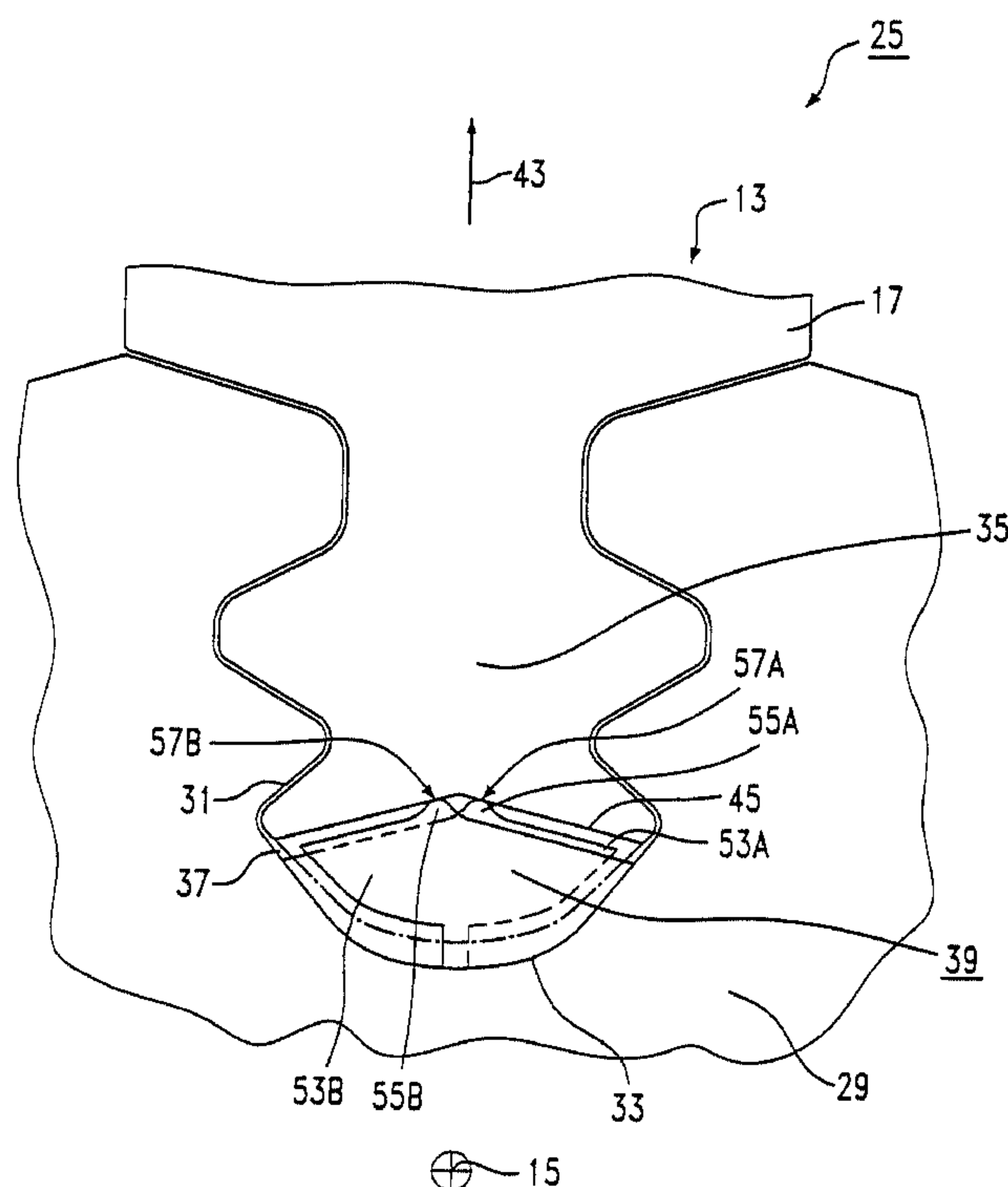
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(54) Titre : TURBOMACHINE AINSI QU'ELEMENT D'ETANCHEITE POUR UN ROTOR D'UNE TURBOMACHINE

(54) Title: TURBOMACHINE AND SEALING ELEMENT FOR A ROTOR OF A TURBOMACHINE



(57) **Abrégé/Abstract:**

The invention relates to a turbomachine (1) with a rotor (25) that extends along a rotational axis (15). Said rotor (25) has a rotor shaft groove (31) with a groove base (33) and a rotor blade (13) with a blade footing (35). Said blade footing (35) is introduced into the rotor shaft groove (31) and a gap (37) is formed between the blade footing (35) and the groove base (33). A sealing element (39) is provided for sealing said gap (37). Said sealing element is at least partially accommodated by the blade footing (35) and is mobile in relation to the same. The invention also relates to a sealing element (39), especially for a rotor (25) of a turbomachine (1), comprising a first partial sealing element (53A) and a second partial sealing element (53B). The inventive sealing element (39) performs its sealing action under the influence of an external force, especially the centrifugal force.



Abstract

The present invention relates to a turbomachine (1) with a rotor (25) that extends along the axis of rotation (15). The rotor (25) incorporates a rotor shaft groove (31) with a groove base surface (33), as well as a blade (13) with a blade footing (35). The blade footing (35) is inserted into the rotor shaft groove (31), and a gap is formed between the blade footing (35) and the groove base surface (33). A sealing element (39) is provided to seal the gap (37) and this is accommodated in part in the blade footing (35) and can move relative to this. The invention also relates to a sealing element (39), in particular one for a rotor (25) of a turbomachine (1), with a first partial sealing element (53A) and with a second partial sealing element (53B). The sealing element (39) fulfills its sealing function when acted upon by an external force, in particular by centrifugal force.

Figure 4

Turbomachine and Sealing Element for a Rotor of a Turbomachine

The present invention relates to a turbomachine with a rotor that extends along an axis of rotation, said rotor incorporating a rotor shaft groove as well as a rotor blade with a blade footing that is inserted into the rotor shaft groove, a gap being formed between the blade footing and the rotor shaft groove. The present invention also relates to a sealing element for a rotor of a turbo machine.

The blades of turbomachines, for example of gas or steam turbines or compressors, are secured in various configurations across the complete periphery in the peripheral surface of a rotor shaft which, for example, incorporates a rotating rotor disc. Usually, turbine blade has a blade portion proper, a blade platform, and a blade footing with an attachment structure that is accommodated in a rotor shaft groove that is configured in an appropriately complementary form in order to attach the rotor blade. This rotor shaft groove can be in the form of a peripheral groove or an axial groove in the peripheral surface of the rotor shaft. The rotor shaft groove has a groove base. Once the blade footing of a rotor blade has been inserted into the rotor shaft groove, because of the design, a gap is formed as a result of the rotor components that are juxtaposed. When the rotor is operating, this gap can give rise to leakage flows of coolant, or of an action fluid that drives the rotor, through the gap. Such a gap is formed between the blade footing and the groove base. A gap of this kind can also be formed between two blade platforms of blades that are adjacent to each other in the peripheral direction, as well as between the peripheral surface of the rotor shaft and a blade platform that is radially adjacent to the peripheral surface. In order to

possible leakage flows through the gap, such as the escape of coolant, e.g., of cooling air into the flow channel of a gas turbine, much effort has been expended with the objective of finding an effective sealing concept. Such a solution must be resistant to the temperatures that are generated and the mechanical loads that result from the considerable centrifugal forces generated by the rotating system.

DE 198 10 567 A1 describes a sealing plate for a blade of a gas turbine. If cooling air that is routed to the blade escapes into the flow channel, this will—amongst other things—reduce the efficiency of the turbine. The sealing plate, which is inserted into a gap between the blade platform of two adjacent blades, is meant to prevent leakage as consequence of cooling air escaping. An additional sealing effect is achieved by sealing pins that are similarly incorporated between the blade platforms of two adjacent blades. A number of such sealing pins are required in order to achieve the desired sealing effect, so as to prevent the egress of cooling air from adjacent blade platforms.

US Patent Specification 4,021,138 describes a sealing concept for a rotor of a gas turbine with a rotor disk and a blade with a cooled interior space. The rotor disk has a face surface and a rear surface that is opposite it along the axis of rotation of the face surface, as well as an axial rotor disk groove that extends from the face surface into the rear surface. The blade has a blade footing that is accommodated by the axial blade disk groove. Within the rotor disk, a coolant chamber is adjacent radially inwards to the blade footing, and this passes completely through the rotor disk

in an axial direction from the face surface right through to the rear surface. There are coolant channels in the blade and these extend from the blade footing as far as the blade proper in a radial direction and are connected to the coolant chamber so as to permit a flow and so that a coolant can pass from the coolant chamber into the coolant channels so as to cool the interior of the blade. To this end, the coolant chamber is acted upon by a coolant, by way of a coolant feed that is arranged axially ahead of the face surface. In order to seal the coolant chamber so as to prevent the coolant from escaping, a first seal plate is arranged on the face surface, and a second seal plate is arranged on the rear surface of the rotor disk. In order to enhance the seal, the side of the first seal plate, which is proximate to the face surface, incorporates a channel that extends in the peripheral direction of the rotor disk and is open towards the face surface. The channel is defined in the radial direction by an outer edge area that is arranged radially outward, and by an inner edge area that is arranged radially inward and opposite the outer edge area, the outer and the inner edge areas butting against the face surface. The outer edge area is so configured that the part of the canal that is adjacent to the face surface is inclined toward the face surface normal line, this direction having a component that is oriented radially outward. A seal bar is disposed loosely within the channel, across the arcuate extent thereof. When the rotor is operating, when it is acted up by centrifugal force, the seal bar moves radially outward in the channel, toward the disk, where it ultimately takes up its sealing position. In the sealing position, the seal rod is in contact with the face surface and seals a gap that is formed between the face surface and the side of the seal plate that is proximate to the face surface. In this way, coolant is largely prevented from escaping through the gap, from the coolant chamber, or from the coolant feed. Because relatively large seal plates are used, and because of the additional seal bars, this solution is

extremely costly. In addition, maintenance and repairs to the rotor can only be effected once these sealing components have been removed from the rotor.

EP 0 799 974 A2 describes a seal element for a rotor of a turbomachine. The turbomachine has a rotor with a rotor disk that is arranged radially inward, a plurality of blades being secured radially outward in the peripheral direction of the rotor disk, thereby forming a gap in each instance. Cooling channels are provided to cool the rotor; these extend through the rotor disk and the blades in a radial direction. In order to limit the egress of coolant (leakage) from the gap, in the area of the blade attachment, a seal element is arranged between the blade footing and the rotor disk. When acted upon by centrifugal force, the seal element tips and thereby moves into its sealing position. In order to secure the seal element from falling out of the gap in the direction of the axis of rotation, the seal element has two safety lugs that fit around a projection on the blade footing that is formed radially inward, the seal element, in particular one of the safety lugs, extending at least partially out of the gap, from the face side of the rotor disk.

It is the objective of the present invention to describe a turbomachine with a rotor that incorporates a rotor shaft groove and a groove base surface, as well as a blade with a blade footing, said blade footing being inserted into the rotor shaft groove, and with a sealing element. In particular, said sealing element is intended to permit the efficient limitation of axial leakage, and to be as resistant as possible to mechanical and thermal loads that occur. A further objective of the present invention is to describe a sealing element, in particular for a rotor of a turbomachine.

According to the present invention, the first of these objectives is achieved by a turbomachine with a rotor that extends along an axis of rotation, which has a rotor shaft groove with a groove base surface, as well as a blade with a blade footing, said blade footing being inserted into the rotor shaft groove, forming a gap between the blade footing and the groove base, a sealing element being provided to seal said gap, this being accommodated at least in part by the blade footing, the sealing element being movable towards the blade footing, the sealing element being in contact with the groove base when acted upon by centrifugal force, thereby sealing the gap.

The present invention proceeds from the idea that when a turbomachine—such as a gas or steam turbine, or a compressor—is operating, the rotor is exposed to an action fluid, e.g., hot gas, steam, or heated air, that flows along it. When this happens, the action fluid can act on the blades as a consequence of expansion, and thereby cause said blades to rotate about the axis of rotation. The rotor that has the blades is therefore subjected to great loads, both thermal and mechanical, in particular because of the centrifugal force that results from such rotation. A coolant, e.g, cooling air, is used to cool the rotor, mainly the blades thereof, and this is usually routed to the rotor through suitable coolant feeds. This means that leakage of coolant, as well as of the action fluid—so-called gap losses—can occur in the gap formed by the blade footing and the groove base. This leakage has a most deleterious effect on cooling efficiency as well as on the ruggedness of installation (smoothness of operation, creep strength) of the blades in the rotor shaft groove.

The present invention presents a new possibility for sealing the gap against possible leakage. This is achieved, firstly, by the fact that the sealing element is accommodated, at least in part, by the blade footing and is movable relative to this. Second, the centrifugal force that is generated when the turbomachine is operating, i.e., by the rotation of the rotor, is exploited for sealing purposes. The blade footing thus serves to accommodate the sealing element as well as for the attachment of the blades. In addition, such a configuration guides the sealing element within the blade footing. The gap extends in a radial and in an axial direction, as well as in a peripheral direction of the rotor, the axial extent of the gap usually being the dominant dimension; the extent of the gap in the peripheral direction being greater than the radial dimension. The exact geometry of the gap is determined by the specific configuration of the rotor shaft groove and the groove base, as well as of the blade footing. The sealing element can be matched individually to the particular geometry of the rotor and the demands that are imposed with respect to the leakage that is to be reduced.

According to the present invention, the sealing element seals the gap because of the action of centrifugal force. When the turbomachine is operating, the sealing element is moved into its sealing position as a result of rotation, by the outwardly acting centrifugal force, when it fulfills its sealing function, when the sealing element is pressed firmly against the base of the groove, and thus seals the gap.

An important advantage vis-à-vis conventional sealing concepts is achieved by sealing the gap in a purposeful manner. Because of this, it is possible to arrive at a very compact construction.

Extended sealing elements, which are very costly, are rendered unnecessary. The sealing element is arranged where it is required in order to provide efficient restriction of leakage. When the rotor is operating, the sealing element moves into its sealing position, where it fulfills its sealing function. When this happens, the sealing element comes into contact with the groove base, and is pressed firmly against the groove base. Because of the fact that the sealing element is also—at least in part—accommodated by the blade footing, the gap is sealed. In this way, for example, the ingress of an action fluid, e.g., the hot gas in a gas turbine, into the gap is effectively prevented. This protects the material of the rotor, in particular the material of the blade footing, against high temperatures and the potentially oxidizing and corrosive effects of the action fluid. By suppressing leaks of action fluid and/or coolant into the gap with the sealing element, temperature gradients in the area of the blade attachments are avoided. Possible thermal stresses, which result from preventing thermal expansion between adjacent rotor components at different temperatures, are reduced thereby. The blade footing of a blade and the rotor shaft groove that accommodates and fixes the blade can thus be manufactured with far smaller tolerances. A smaller tolerance is advantageous for the mechanical stability of the installed blade and the smoothness with which the rotor operates.

In particular, the close tolerance fits that are used to secure the blade footing in the rotor shaft groove can be provided with less free play. This also reduces leakage through the fits. Since the sealing element is accommodated at least in part in the blade footing, on the one hand it is securely held and secured against falling out of the rotor; on the other hand, it is protected against being acted upon directly by the action fluid. The sealing element is not necessarily coupled

securely to a blade, in particular to a blade footing. This simplifies installation or repair work on a blade, such as, for example, replacement of a blade, which can be effected at no great cost. The sealing element remains largely undisturbed, and can thus be used repeatedly.

It is preferred that the rotor have a disk that includes the rotor shaft groove with the groove base surface, the rotor shaft groove extending along a transverse axis that is inclined towards a plane perpendicular to the axis of rotation. The attachment of the rotatable blade in the rotor shaft groove is effected in such a way that when the rotor is operating it absorbs the blade stresses caused by flow and centrifugal forces and well as blade oscillations very reliably, and can transfer the forces that are generated onto the blade disk and ultimately to the whole of the rotor. The attachment of the blade can be effected, for example, by axial grooves, a blade being clamped in a blade disk groove that extends essentially in an axial direction and is specially provided for this purpose. For smaller stresses, e.g., in the case of the blades in axial compressors, it is possible to use simple attachments for the blade, for example, those that incorporate a swallow-tail or Laval root. For steam turbine end stages that have long blades and thus greater centrifugal forces acting on the blade, in addition to the so-called insertion root there are also axial Christmas-tree roots. The axial Christmas tree attachment is preferably used in blades that are subjected to a high level of thermal stresses in gas turbines. In this case, the rotor shaft groove can extend along the transverse axis across the whole of the rotor disk. The gap between the groove base and the blade footing is then open radially and extends along the transverse axis accordingly.

It is preferred that the sealing element be arranged in a recess, in particular in a groove, in the blade footing. The sealing element is secured against falling out, and it is secured against being ejected when acted upon by centrifugal force in stationary operation or when the rotor is subjected to transient loads, in that the sealing element is arranged in a suitable recess in the blade footing. Additionally, the recess provides a reaction surface in the blade footing, which is most expediently formed as a partial surface. In the case of a groove, this reaction surface is formed on the groove base. The reaction surface is then arranged radially outward in the blade footing, and is opposite the groove base surface of the rotor shaft groove, in a radial direction.

In order to achieve the best possible sealing effect when the sealing element fits into the recess, the reaction surface incorporates appropriately small and well-defined surface roughness. After the actual production of the recess, in particular the groove, for example by removal of material from the blade footing by milling or turning, a reaction surface with the desired roughness can be produced on the groove base by polishing a reaction surface.

It is preferred that the blade footing have a first blade footing edge and a second blade footing edge that is opposite the first blade footing edge along the axis of rotation, as well as a blade footing centre area that is arranged centrally between the first blade footing edge and the second blade footing edge, a sealing element being arranged in the area of the first blade footing edge and/or of the second blade footing edge and/or the blade footing centre area. Relative to the direction of flow of an action fluid—such as the hot gas in a gas turbine—the first blade footing edge is arranged upstream, and the second blade footing edge is arranged downstream.

Depending on the structural details and requirements with respect to the sealing effect that is to be achieved in the gap, this geometrical organization permits a configuration and arrangement of the sealing element or a plurality of sealing elements in different sub-areas of the blade footing.

The arrangement of a sealing element in the area of the first, upstream, blade footing edge mainly limits the ingress of moving, possibly extremely hot, action fluid into the gap, and thereby prevents damage to the rotor. The arrangement of the sealing element in the area of the second, downstream, blade footing edge mainly serves to restrict the egress of coolant, e.g., cooling air that is at a specific pressure in the gap, upstream in an axial direction, along the groove base into the flow channel. Since the action fluid expands in the direction of flow, the pressure of the action fluid grows progressively lower in the direction of flow. A coolant that is under a specific pressure in the gap will thus emerge from the gap in the direction of the lower ambient pressure, which is to say on the downstream, second, blade footing edge. Because of this, it is advantageous to provide a sealing element in the area of the second blade footing edge. The blade footing centre area forms another sub-area of the blade footing. Together with the first and the second blade footing edge, there are thus a number of possibilities for arranging a sealing element in different sub-areas of the blade footing. In the case of rotor blades that have an internal cooling system, in which a suitable coolant such a cooling air is fed to the rotor blade through a suitable coolant feed that is arranged in the blade footing centre area, the sealing element is best arranged in the area of the first or second blade footing edge. In the case of rotor blades that do not incorporate an internal cooling system of this kind, arranging the sealing element in the area of the blade footing centre area can be just as advantageous.

It is preferred that a plurality of sealing elements be incorporated. The number and the arrangement of these will be determined on the basis of the structural details and requirements vis-à-vis the sealing effect that is to be achieved; combinations of a plurality of sealing elements can also be used. As far as adaptation to a concrete task is concerned, the sealing concept offers great flexibility. For example, the combination of a sealing element in the area of the first blade footing edge and an additional sealing element in the area of the second blade footing edge seals the gap from two sides and thus offers a high level of protection against the ingress of action fluid into the gap and against the egress of coolant from the gap into the flow channel of the turbomachine. Amongst other things, the escape of coolant into the flow channel degrades the efficiency of the turbomachine. In this respect, a multiple arrangement of sealing elements is very advantageous.

It is preferred that the sealing element extend in a plane perpendicular to the axis of rotation. The gap extends both radially and axially, and in the peripheral direction of the rotor. A sealing element that extends in a plane perpendicular to the axis of rotation is thus particularly well suited to preventing any possible axial leaks. Thus, for example, a leakage flow that is oriented upstream, for example, a hot gas from the flow channel of a gas turbine, which spreads along the base of the groove, is effectively prevented by the sealing element. The leakage flow is impeded by the obstacle in the form of the sealing element in the gap, and is ultimately stopped on the side of the sealing element that is faces the leakage flow (simple choke). The side of the sealing element that is remote from the leakage flow and the part of the gap that is adjacent thereto in an

axial direction are already protected against being acted upon by the leaking medium, e.g., a hot action fluid or a coolant, by the simple sealing element. A distinct improvement of this simple solution with a single sealing element that extends in a plane perpendicular to the axis of rotation, results from the combination of the sealing element with one or more additional sealing elements that also extend in a plane perpendicular to the axis of rotation, and which are arranged so as to be spaced apart from the sealing element. Any possible leakage flows in the gap are greatly reduced by this multiple arrangement of sealing elements.

It is preferred that the sealing element can move in an axial direction. This ensures that when the sealing element is being acted upon by centrifugal force it moves away from the axis of rotation of the rotor in a radial direction. This effect is exploited in order to achieve a greatly enhanced sealing effect within the gap. When acted upon by centrifugal force, the sealing element comes into contact with a reaction surface that is arranged radially outward, which is configured, for example, as a sub-area of a recess, in particular a groove. The sealing element is pressed firmly against the reaction surface. If the centrifugal force and the reaction forces, together with their force components on the reaction surface, are utilized in an appropriate manner, this will ensure that the sealing element comes into contact with the base of the groove and is simultaneously pressed firmly against the base of the groove. Sufficient radial movement of the sealing element is ensured by suitable dimensions of the recess, in particular of the groove, in the blade footing and of the sealing element.

It is also advantageous that because of the foregoing, the sealing element can be removed in a problem free manner for maintenance or if the blade fails—without the need for any special tools and without the danger of the sealing element having become hardened and made brittle because of oxidization or corrosive attack at high operating temperatures—and replaced, should this be necessary. Furthermore, a specific clearance for the sealing element, which fits in the recess—in particular into the groove—in the blade footing is very useful because, as a result of this, thermal expansion can be permitted and as a consequence thermally induced stresses between the sealing element and the adjacent groove base surface, and the blade footing, can be avoided.

It is preferred that the sealing element have a first partial sealing element and a second partial sealing element, and that these be movable relative to each other. The partial sealing elements can be so configured that they assume—in a special way—a partial sealing function for different areas in the gap that are to be sealed, in particular for different areas of the surface of the groove base. The partial sealing elements complement each other, by their paired arrangement, to form a sealing element, the sealing effect of a paired system of partial sealing elements being greater than that achieved by a single sealing element. As a result of a specially adapted configuration of the partial sealing elements to the particular areas in the gap that are to be sealed, it is possible for the sealing effect of the paired arrangement to be greater than could be achieved by a one-piece sealing element. A particularly flexible and efficient system of partial sealing elements is realized because of the relative mobility of the partial sealing elements. Provision is made for both translational and well as rotational movements of the partial sealing elements relative to each other. If the partial sealing elements extend in a plane perpendicular to the axis of rotation,

for example, the relative movements in this plane are essentially limited. The relative mobility of the partial sealing elements permits a well adapted system that is configured as a function of the thermal and/or mechanical loads on the rotor and the specific geometry of the gap that is to be sealed. The adapted system of partial sealing elements is so configured and supported that to a certain degree it is self-adjusting when acted upon by external forces, e.g., centrifugal forces and well as normal and bearing forces (reaction forces), when its sealing action becomes effective. More advantageously, any possible thermally or mechanically induced stresses are better balanced out by the pair of partial sealing elements than is the case with conventional sealing concepts.

It is preferred that a first area of rotation with a first axis of rotation be associated with the first partial sealing element, and a second area of rotation with a second axis of rotation be associated with the second partial sealing element.

It is preferred that each of the partial sealing elements be so configured that it is supported so as to be able to rotate about a particular axis of rotation. In the event that the sealing elements extend in a plane perpendicular to the axis of rotation of the rotor, the rotation of the partial sealing elements is restricted in this plane. This permits better sealing of the gap, because each partial sealing element is moved into a favourable sealing position by the rotation. In this way, an improved sealing effect is achieved independently for each partial sealing element. The axis of rotation of a partial sealing element can also be formed as a point of contact (axis of contact) of the area of rotation with a suitable contact surface, e.g., with a reaction surface that is adjacent

to the area of rotation. The reaction surface is advantageously produced in the blade footing as a partial surface of a recess, in particular a groove. The first axis of rotation and the second axis of rotation can be different from each other or can be identical. In the latter case, the first partial sealing element and the second partial sealing element have a common axis of rotation.

It is preferred that the centre of gravity of the first partial sealing element be so arranged relative to the first axis of rotation, and the second partial sealing element be so arranged relative to the second axis of rotation that the moments of rotation that result from the action of centrifugal force act in opposite directions. Because of the resulting, opposing moments of rotation, the partial sealing elements are rotated about their axes of rotation in opposite directions relative to each other. The centrifugal force acts in the same way, radially outward, for both partial sealing elements, and acts on the particular centre of gravity. The vertical connecting vector from the centre of gravity of one of the partial sealing elements to the associated axis of rotation, together with the centrifugal force vector forms a right-hand system, for example. In this case, the vertical connecting vector from the centre of gravity of the other partial sealing system to the axis of rotation that is associated with the other partial sealing element, together with the centrifugal force vector, form a left-hand system, so that the resulting moments of rotation are opposite to each other. This is ensured by appropriate design configuration of the partial sealing elements with respect to the distribution of weight, in particular the position of the particular centre of gravity, as well as the support for the partial sealing elements with respect to the axis of rotation.

It is preferred that the first partial sealing element and the second partial sealing element have the same geometry. The partial sealing elements can be converted into one another by rotation, or mirror imaging, or symmetry operations comprising combinations of these. From the standpoint of production technique, this is a particularly favourable solution, especially if the first partial sealing element and the second partial sealing element are configured identically with respect to their structures. Then, only one form of the partial sealing element has to be made, and this can be done by turning or milling it from a work piece or by casting it with the help of a suitable mould. A first partial sealing element and an additional, identical, second sealing element can thus be very simply paired to form a sealing element. This is extremely cost effective.

A further, improved sealing effect in the gap is achieved in that, in one preferred configuration, the first partial sealing element and the second partial sealing element overlap in the peripheral direction. This overlapping in the peripheral direction effectively prevents any possible leakage flow. The first partial sealing element and the second partial sealing element can in each instance have a groove base sealing edge that abuts against the groove base, as well as an opposite rotation edge along the radial direction of the groove base sealing edge, said rotation edge including the area of rotation. When the rotor is operating, i.e., when it is acted upon by centrifugal force, the groove base sealing edge of the first partial sealing element and the groove base edge of the second partial sealing element each come into contact with the groove base surface and seal the gap. The system made up of partial sealing elements is so configured that because of the overlapping of the partial sealing elements in the peripheral direction, the gap is

sealed, particularly in an axial direction, the partial sealing elements complementing each other's sealing effect in an advantageous manner.

More advantageously, the first partial sealing element and the second partial sealing element are arranged so as to be axially adjacent to each other. The partial sealing elements can also adjoin each other; this results in a system of partial sealing elements that is mutually and mechanically stabilizing. This makes it easier for the partial elements to slide toward each other so as to achieve their sealing positions precisely, when the rotor is operating. The system of partial sealing elements that has been described is so executed that when acted upon by external forces such as centrifugal force, as well as by normal and bearing forces, it adjusts itself in order to achieve the desired sealing effect in the gap. When this is done, a particularly good interlocking fit is realized in the gap, particularly on the base surface of the groove, as a result of the paired arrangement.

It is preferred that the sealing element be manufactured from a material that is resistant to high temperatures, in particular an alloy that is based on nickel or cobalt. In addition, these alloys also have sufficiently elastic deformation characteristics. It is preferred that the material used for the sealing element be so selected as to match the material used for the rotor, so that impurities or diffusion damage are largely prevented. Furthermore, this will ensure uniform thermal expansion or contraction of the sealing element with the sealing element.

It is preferred that the turbomachine be a gas turbine.

According to the present invention, the objective of a rotor of a turbomachine has been achieved by a sealing element, in particular for the rotor of a turbomachine, that has a first partial sealing element and a second partial sealing element which are mobile relative to each other, and in which a first area of rotation with a first axis of rotation is associated with the first partial sealing element, and a second area of rotation with a second axis of rotation is associated with the second partial sealing element, the centre of gravity of the first partial sealing element being so arranged relative to the first axis of rotation, and the second partial sealing element being so arranged relative to the second axis of rotation that the turning moments that are generated on both partial sealing elements by the dynamic effect act in opposition to each other. The dynamic effect on the two partial sealing elements can be caused, for example, by centrifugal force in a rotating system. In a special way, the sealing element is well suited for sealing the gap that is formed between the blade footing and the base surface of the groove in a turbomachine, e.g., a gas or steam turbine or a compressor, which has a rotor that extends along the axis of rotation and incorporates a rotor shaft groove with a groove base, as well as a blade with a blade footing, said blade footing being inserted into the rotor shaft groove. The gap is sealed against possible leakage flows of, for example, action fluid or a coolant. The sealing element can also be used in other rotating systems, in which a flow of fluid, in particular a leakage flow, is to be sealed off. Possible uses for the sealing element are to be found, for example, in rotors or rotor disks used in engines or power plants that have hydraulic and/or pneumatic systems with a fluid, e.g., a fuel or lubricating agent (oil), as well as in internal combustion engines or aircraft power plants with an operating medium.

It is preferred that the first partial sealing element and the second sealing element have the same geometry. The partial sealing elements can be converted into one another by rotation, or mirror imaging, or symmetry operations comprising combinations of these. A particularly advantageous configuration is such that the first partial sealing element and the second partial sealing element are identical components from the construction standpoint. This means that only one component has to be manufactured, which can be done by casting it with the help of a mould, or by turning or milling.

The present invention will be describe in greater detail below on the basis of embodiments shown in the drawings appended hereto. These drawings show the following:

- Figure 1: A half section through a gas turbine with a compressor, a combustion chamber, and a turbine;
- Figure 2: A perspective view of part of a rotor disk of a rotor;
- Figure 3: A perspective view of part of a rotor disk with a blade inserted in it;
- Figure 4: A part of the arrangement shown in Figure 3, in cross section on the line IV-IV, with a sealing element;
- Figure 5: A perspective view of a sealing element with a first partial sealing element and with a second partial sealing element;
- Figure 6: A plan view of the first partial sealing element and the second partial sealing element, perpendicular to the axis of rotation;

- Figure 7: A side view of a blade with an internal cooling system, and with a sealing element;
- Figure 8: A side view of a blade with an internal cooling system, with an alternative arrangement of a sealing element shown in Figure 7.
- Figure 9: A cross section through part of a rotor, with a peripheral groove and an inserted blade;
- Figure 10: A cross section of part of a rotor with a configuration of the blade attachment that is an alternative to that shown in Figure 9.

Identical part numbers are used for identical parts in the individual drawings.

Figure 1 is a half cross section through a gas turbine 1. The gas turbine 1 incorporates a compressor 3 for combustion air, a combustion chamber 5 with burners 7 for a liquid or gaseous fuel, and a turbine 9 that drives the compressor 3 and a generator (not shown in Figure 1).

Within the turbine 9 there are fixed guide vanes 11 and rotating rotor blades 13 on collars (not shown in cross section) that each extend radially along the axis of rotation 15 of the gas turbine 1. A pair, made up of a collar of fixed guide vanes 11 (guide vane collar) and a collar of rotating blades 13 (blade collar), is referred to as a turbine stage. Each guide vane 11 has a vane platform 17 that is arranged to attach a particular guide vane 11 on the inner housing 19 of the turbine.

The vane platform 17 thus forms a wall element in the turbine 9. The vane platform 17 forms an outer limit of the flow channel 21 through which a hot action fluid A flows when the turbine 9 is in operation. The blade 13 is secured on the turbine rotor 23 that is arranged along the axis of

rotation 15 of the gas turbine 1 through an appropriate vane platform 17. The turbine rotor 23 can be made up of, for example, a plurality of rotor disks (not shown in Figure 1) that accommodate the blades 13; these are held together by a tie rod (not shown herein) and centred on the axis of rotation 15 by serrations in such a way as to tolerate thermal expansion. Together with the blades 13, the turbine rotor forms the rotor 25 of the turbomachine 1, in particular of the gas turbine 1. When the gas turbine is operating, air L is drawn in from the surroundings, and compressed and simultaneously pre-heated in the compressor 3. The air L is combined with the liquid or gaseous fuel in the combustion chamber 5, and burned; this generates a hot action fluid A. Some of the air L that is has been removed earlier from the compressor 3 through suitable bleed points 27 serves as cooling air K that is used to cool the turbine stages, the first turbine stage is acted upon by a turbine inlet temperature of approximately 750°C to 1200°C. The hot action fluid A, hereinafter referred to as the hot gas A, is expanded and cooled in the turbine 9; this hot gas flows through the turbine stages, thereby causing the rotor 25 to rotate. In order to provide interior cooling of the blades 13, the cooling air K is routed through suitable supply lines (not shown herein) to the blades 13 by way of the turbine disk 23. After it leaves the bleeds 27 in the compressor 3, the cooling air K first flows upstream along the axis of rotation 15 in the turbine disk 23 and then radially outward through the rotor 25, after which it reaches the blade 13, which it cools. An internal cooling system of this kind for a blade 13 is used to ensure the efficient cooling for a blade, particularly in the case of rotors 25 that are under extremely high thermal loads.

Figure 2 is a perspective view of part of a rotor disk 29 of a rotor 25. The rotor disk 29 is centred along the axis of rotation 15 of the rotor 25. The rotor disk 29 has a rotor shaft groove 31 for securing a blade 13 of the gas turbine 1. The rotor shaft groove 31 extends along a transverse axis 41 that is inclined relative to a plane that is perpendicular to the axis of rotation 15. The transverse axis 41 subtends an angle that is other than 0° with the axis of rotation 15. The transverse axis 41 can, however, be parallel to the axis of rotation 15. The rotor shaft groove 31 has a groove base 33 that is arranged on the bottom of the rotor shaft groove 31 and extends along the transverse axis 41. The rotor shaft groove 31 is configured as an axial blade groove, in particular as an axial Christmas tree groove. In this way it is possible to achieve reliable attachment of the blade 13, the blade loadings generated by flow and centrifugal forces—as well as blade oscillations—being absorbed with a high degree of safety, and effective transmission of the forces that are generated onto the rotor disk 29 and ultimately to the rotor 25 as a whole, being ensured.

Figure 3 is a perspective view of part of a rotor 14. The rotor 25 has a rotor disk 29 and a blade 13. The rotor disk 29 incorporates a rotor shaft groove 31 with a groove base 33. The blade 13 extends along a longitudinal axis 43 that is oriented radially outwards and includes—following each other in sequence along the longitudinal axis 43—a blade footing 35, a vane platform 17, and a blade proper 65 that adjoins the blade platform 17, which is shown only in part. The blade footing 35 of the blade 13 is inserted into the rotor shaft groove 31 along the direction of insertion 41 of the rotor disk groove 31. A gap 37 is formed between the blade footing 35 and the groove base 33, and this extends along the direction of insertion 41. A hot gas A that flows

past the blade proper 65 generates torque in the rotor disk 29. At elevated operating temperatures of the rotor 25, the blade proper 65 of the blade requires internal cooling, the supply lines 63 for which extend along the longitudinal axis 43 of the blade 13 within the blade proper 65. The supply lines 63 are part of an internal cooling system that is not shown in greater detail. A coolant K, for example cooling air K, is routed through a feed line (not shown herein), through the rotor disk 29 into the blade footing 35 of the blade 13, and from there through the supply line 63 into the blade proper 65. The gap 37 is sealed in order to prevent the egress of a coolant K, in particular cooling air K, from the gap 37, and to limit the ingress of hot gas A into the gap 37 (see Figure 4).

Figure 4 shows part of the arrangement shown in Figure 3, along the line IV-IV, with a sealing element 39 that seals the gap 37. The sealing element 39 extends in a plane that is perpendicular to the axis of rotation 15, and is arranged in a recess, in particular in a groove, in the blade footing 35 and is thus accommodated in part by the blade footing 35. The sealing element 39 has a first partial sealing element 53A and a second partial sealing element 53B; these are movable relative to each other. The first sealing element 53A and the second sealing element 53B overlap each other in the peripheral direction and are arranged along the axis of rotation 15 so as to be adjacent to each other. A first rotation area 55A with a first axis of rotation 57A is associated with the first partial sealing element 53A, and a second rotation area 55 B with a second axis of rotation 57B is associated with the second partial sealing element 53B. The axes of rotation 57A, 57B are secured in each case through the point of contact (axis of contact) of the areas of

rotation 55A, 55B on the groove base of the recess 45, which extends radially outward and is adjacent to the areas of rotation 55A, 55B. The axes of rotation 57A, 57B are different axes, and extend essentially parallel to the axis of rotation 15. This means that the partial sealing elements 53A, 53B can in each instance rotate about the axis of rotation 57A, 57B. Because of their configuration and arrangement, the partial sealing elements 53A, 53B can execute rotational and translational movements, or combinations of rotational and translational movements. When the rotor 25 is operating, the sealing element 39 seals the gap 37 under the action of centrifugal force. When this takes place, each of the sealing elements 53A, 53B is moved into its sealing position as a consequence of the centrifugal force that acts radially outward, along the longitudinal axis 43, when their sealing action becomes effective. Each partial sealing element 53A, 53B is pressed firmly against the groove base 33, and seals the gap 37. The sealing effect is achieved in that—because of the action of centrifugal force—each partial sealing element 53A, 53B rotates about the rotational axis 57A, 57B until there is interlocking contact of the partial sealing elements 53A, 53B with the groove base 33. The relative movement of the partial sealing elements 53A, 53B results in a system that matches the geometry of the gap and is produced regardless of the thermal and/or mechanical loads on the rotor 25 and the structural configuration of the gap 37 that is to be sealed. The system of partial sealing elements that can move relative to each other is so configured that under the action of external forces such as centrifugal force, as well as normal and bearing force (reaction forces), it adjusts itself and thereby assumes its sealing position. The partial sealing elements 53A, 53B are so configured and installed in the recess 45 that under the action of centrifugal force the rotational moment on the first partial sealing element 53A is oriented in the opposite direction to the rotational moment on the second

partial sealing element 53B. Thus, each of the partial sealing elements 53A, 53B rotates in an opposite direction to the other until such time as they reach their sealing positions. Because of this rotation of the partial sealing elements in opposite directions, they are moved relative to each other in a scissors motion so the sealing element is held particularly securely in the sealing position. The sealing element 39, comprising a pair of partial sealing elements 53A, 53B, seals the gap 37 on the groove bottom 33 against the centrifugal force that is directed in the direction of the longitudinal axis 43. Thus the sealing element 39 seals the gap 37 in a particularly advantageous and efficient manner. In addition, because of the movable pair of partial sealing elements 53A, 53B, that are arranged in pairs to form the sealing element 39, any thermally or mechanically induced stresses are balanced out far better than in conventional seals.

Figure 5 shows a preferred embodiment of the sealing element 39 that is shown in Figure 4.

Figure 5 is a perspective drawing of a sealing element 39 with a first partial sealing element 53A and with a second partial sealing element 53B. The centres of gravity of the first partial sealing element 53A is so arranged relative to the first axis of rotation 57A, and the centre of gravity 59B of the second partial sealing element 53B is so arranged relative to the second axis of rotation 57B that the turning moments 61A and 61B that are generated by the centrifugal force that is oriented radially outward along the longitudinal axis 43 act in opposite directions. The first partial sealing element 53A and the second partial sealing element 53B have the same geometry, which is particularly advantageous from the standpoint of production technique.

Figure 6 is a plan view of the first partial sealing element 53A and the second partial sealing element 53B as in Figure 5, perpendicular to the axis of rotation 15, which is to say towards the longitudinal axis 43. Relative to the axis of rotation 15, the centre of gravity 59A of the first partial sealing element 53A lies along the peripheral direction 67 opposite the centre of gravity 59B of the second partial sealing element 53B. The same applies to the axes of rotation 57A, 57B that are associated with the partial sealing elements 53A, 53B, so that the rotational moments that result from the action of the force on both partial sealing elements 53A, 53B act in opposite directions. The two partial sealing elements 53A, 53B can move relative to each other, for example along the peripheral direction 67. Because of this, when the sealing element 39 is installed (see Figure 4) the gap 37 is effectively sealed by the action of centrifugal force, the partial sealing elements 53A, 53B reaching their sealing positions after completing a limited relative translational and rotational movement. Thus, the partial sealing elements 53A, 53B supplement each other's sealing effect, so that leakage, in particular along the axis of rotation 15, can be very effectively limited. If the sealing element 39 is used for a rotor 25 of a turbomachine 1, for example a gas turbine, a material that is thermally stable is selected for the sealing element 39; this material should also have sufficiently elastic deformation characteristics. Alloys that are based on nickel or cobalt can be used for this purpose.

The sealing element with the paired arrangement of the partial sealing elements 53A, 53B can be used in various ways for sealing purposes. In order to illustrate this, Figure 7 shows a side view of a blade 13, the interior of which is cooled, and which has a sealing element 39A and an additional sealing element 39B. The blade footing 35 of the blade 13 is inserted into the rotor

shaft groove 31 of the rotor disk 29. The blade footing 35 has a first blade footing edge 47 along the axis of rotation and a second blade footing edge 51 that is opposite the first blade footing edge 47. A blade footing centre area 49 is arranged axially between the first blade footing edge 47 and the second blade footing edge 51. Relative to the direction of flow of the hot gas A, the first blade footing edge 47 is upstream and the second blade footing edge 51 is downstream.

There are coolant passages 63 in the rotor disk 29, as well as in the blade footing centre area 49, and these extend along the longitudinal axis 43 and are connected with the intervening space 37 so as to permit a flow. These coolant passages 63 are part of an internal cooling system (not shown herein) for the blade 13. In order to provide interior cooling for the blade 13, a coolant K, e.g., cooling air, flows through the coolant passages 63 and is routed through the interior cooling system, and through the internal cooling system, through the blade platform 17 and the blade proper 65 of the blade 13. In order to seal the gap 37 to prevent the egress of coolant K, the first sealing element 39A is arranged in the vicinity of the first blade footing edge 47, and the second sealing element 39B is arranged in the vicinity of the second blade footing edge 51. The sealing elements 39A, 39B are each arranged in a recess 45, in particular in a groove, in the blade footing. The sealing elements 39A, 39B are in part accommodated in the blade footing 35.

As has been described in connection with Figures 4 to 6, (although not shown in Figure 7 for reasons of clarity), the sealing elements 39A, 39B are each configured as a system made up of two paired partial sealing elements 53A, 53B (compare, for example, Figure 5). When the rotor 25 is operating, i.e., when it is being acted upon by centrifugal force that acts radially outward along the longitudinal axis 43, the partial sealing elements 53A, 53B come into contact with the

groove base 33, and seal the gap 37. The sealing element 39A seals the gap at the first blade footing edge 47, and the sealing element 39B seals the gap 37 at the second blade footing edge 51 that is arranged downstream from this. This configuration reliably prevents the ingress of hot gas A into the gap 37, as well as the egress of coolant K from the gap 37 into the channel 21 (compare Figure 1) of the rotor 25. Were the coolant K to escape into the channel 21, this would lead –amongst other things–to a degradation of the degree of efficiency.

Figure 8 is a side view of blade 13 without an internal cooling system, with an arrangement of the sealing element 39A and that of an additional sealing element 39B that is an alternative to the arrangement shown in Figure 7. In this arrangement, the sealing element 39A is arranged in the vicinity of the first blade footing edge 47, and the sealing element 39B is arranged in the vicinity of the blade footing centre area 49. The arrangement of the sealing element 39A restricts the ingress of the flow of hot gas A into the gap 37, thereby preventing damage to the rotor 25. A correspondingly greater sealing effect is achieved by this combination of the sealing element 39A and the additional sealing element 39B. The sealing effect described above offers an extremely high degree of flexibility as far as adaptation to a specific application is concerned. In this connection, a multiple arrangement of sealing elements 39A, 39B is a particular advantage.

Other means of attaching a blade are known in addition to attaching a blade 13 in the rotor shaft groove 31 of a rotor disk 29 (axial groove) that is essentially oriented axially. The use of the sealing element 39 that is shown for alternative blade attachments is described below on the basis of Figures 9 and 10.

Figure 9 is a cross section through part of a rotor 25 with a rotor shaft groove 31 with a blade 13 inserted therein. The rotor shaft groove 31 is in the form of a peripheral groove 31 in the rotor shaft 23. The peripheral groove 31 is a so called hammer head [undercut] groove that accommodates the blade footing 35. This form of blade attachment is preferred for short blades 13 that generate a low level of centrifugal force and small bending moments. Within the blade footing 35 there is a recess 45, in particular a groove, in which a sealing element 39 fits. The sealing element 39 extends in the peripheral direction of the rotor shaft 23 and seals the gap 37. The sealing element 39 seals the gap by virtue of centrifugal force and can be made up from two partial sealing elements 53A, 53B (not shown in Figure 9) that overlap in the peripheral direction and can move relative to each other, as can be seen from Figure 5. When the rotor shaft 23 rotates about the axes of rotation 15, the sealing element 39 is pressed firmly against the groove base 33 by the action of centrifugal force. This seals the gap 37.

Figure 10 shows part of a rotor 25 with a configuration of the blade attachment that is an alternative to the one shown in Figure 9. In this, the peripheral groove 31 is produced as a so-called peripheral Christmas-tree foot. The blade footing 35 of the blade 13 is in the form of a Christmas tree root at that fits into the peripheral groove 31, in particular into the peripheral Christmas tree groove 31. Because of this type of attachment for the blade 13, when the rotor 25 rotates about the axis of rotation 15, a very effective transmission of force to the rotor shaft 23 is ensured together with a particularly secure attachment. Analogously to Figure 9, there is a recess

45 in the blade footing 35 and a sealing element 39 is arranged in this. The sealing element 39 serves to seal off the gap 37 that is formed between the blade footing 35 and the groove base 33.

The concept for sealing the gap 37 by means of a sealing element 39, described above, which involves a pair of partial sealing elements 53A, and 53B that can move relative to each other, is extremely flexible and can be applied to a rotor 25, the blade 13 of which is secured in a peripheral groove and 31.

Patent Claims

1. Turbomachine (1) with a rotor (25) that extends along an axis of rotation (25), which incorporates a rotor shaft groove (31) with a groove base surface (33), as well as a blade (13) with a blade footing (35), the blade footing (35) being inserted into the rotor shaft groove (31), a gap being formed between the blade footing (35) and the base surface (33) of the groove, a sealing element (39) being provided in order to seal the gap (37), characterized in that the sealing element (39) is arranged in a recess (45) in the blade footing (35) and is accommodated at least in part in the blade footing (35); in that the sealing element (39) is mobile relative to the blade footing (35); and in that the sealing element (39) is in contact with the base surface (33) of the groove when acted upon by centrifugal force, and thereby seals the gap (37).
2. Turbomachine (1) as defined in Claim 1, characterized in that the rotor (25) has a rotor disk (29) that includes the rotor shaft groove (31) with the groove base surface (33), the rotor shaft groove extending along a transverse axis (41) that is inclined relative to a plane perpendicular to the axis of rotation (15).
3. Turbomachine (1) as defined in one of the Claims 1 or 2, characterized in that the blade footing (35) has a first blade footing edge (47) and a second blade footing edge (51) along the axis of rotation, which is opposite the first blade footing edge, as well as a blade footing centre area (49) that is arranged axially between the first blade footing edge (47) and the

second blade footing edge (51), a sealing element (39) being arranged in the area of the first blade footing edge ((47) and/or of the second blade footing edge (51) and/or of the blade footing centre area (49).

4. Turbomachine (1) as defined in one of the preceding claims, characterized in that a plurality of sealing elements is used.
5. Turbomachine (1) as defined in one of the preceding claims, characterized in that the sealing element (39) extends in a plane perpendicular to the axis of rotation (15).
6. Turbomachine (1) as defined in one of the preceding claims, characterized in that the sealing element (39) is movable in a radial direction (43).
7. Turbomachine (1) as defined in one of the preceding claims, characterized in that the sealing element (39) has a first partial sealing element (53A) and a second partial sealing element (53B), these being movable relative to each other.
8. Turbomachine (1) as defined in Claim 7, characterized in that a first area of rotation (55A) with a first axis of rotation (57A) is associated with the first partial sealing element (53A), and a second area of rotation (55B) with a second axis of rotation (57B) is associated with the second partial sealing element (53B).

9. Turbomachine as defined in Claim 8, characterized in that the centre of gravity (59A) of the first partial sealing element (53A) is so arranged relative to the first axis of rotation (57A) and the centre of gravity of the second partial sealing element (53B) is so arranged relative to the second axis of rotation (57B) that the turning moments (61A, 61B) that result from centrifugal force are opposite to each other.
10. Turbomachine as defined in Claim 8 or Claim 9, characterized in that the first partial sealing element (53A) and the second partial sealing element (53B) have the same geometry.
11. Turbomachine as defined in one of the Claims 8, 9, or 10 , characterized in that the first partial sealing element (53A) and the second partial sealing element (53B) overlap in the peripheral direction.
12. Turbomachine (1) as defined in one of the Claims 8 to 11, characterized in that the first partial sealing element (53A) and the second partial sealing element (53B) are axially adjacent to each other.
13. Turbomachine (1) as defined in one of the preceding claims, characterized in that the sealing element (39) is manufactured from a material that is very resistant to high temperatures, in particular from a nickel-based or a cobalt-based alloy.

14. Turbomachine (1) as defined in one of the preceding claims, characterized by its configuration as a gas turbine (1).
15. Sealing element (39), in particular for a rotor (25) of a turbomachine (1), which has a first partial sealing element (53A) and a second partial sealing element (53B) that are movable relative to each other, and a first area of rotation (55A) with a first axis of rotation (57A) is associated with the first partial sealing element (53A), and a second area of rotation (55B) with a second axis of rotation (57B) is associated with the second partial sealing element (53B), the centre of gravity (59A) of the first partial sealing element (53A) being so arranged relative to the first axis of rotation (57A) of the first partial sealing element (53A), and the centre of gravity (59B) of the second sealing element (53B) being so arranged relative to the second axis of rotation (57B) that the turning moments (61A, 61B) resulting from the action of force on the two partial sealing elements (53A, 53B) are in opposition to each other.
16. Sealing element (39) as defined in Claim 6, characterized in that the geometry of the first partial sealing element (53A) and the geometry of the second partial sealing element (53B) are identical.

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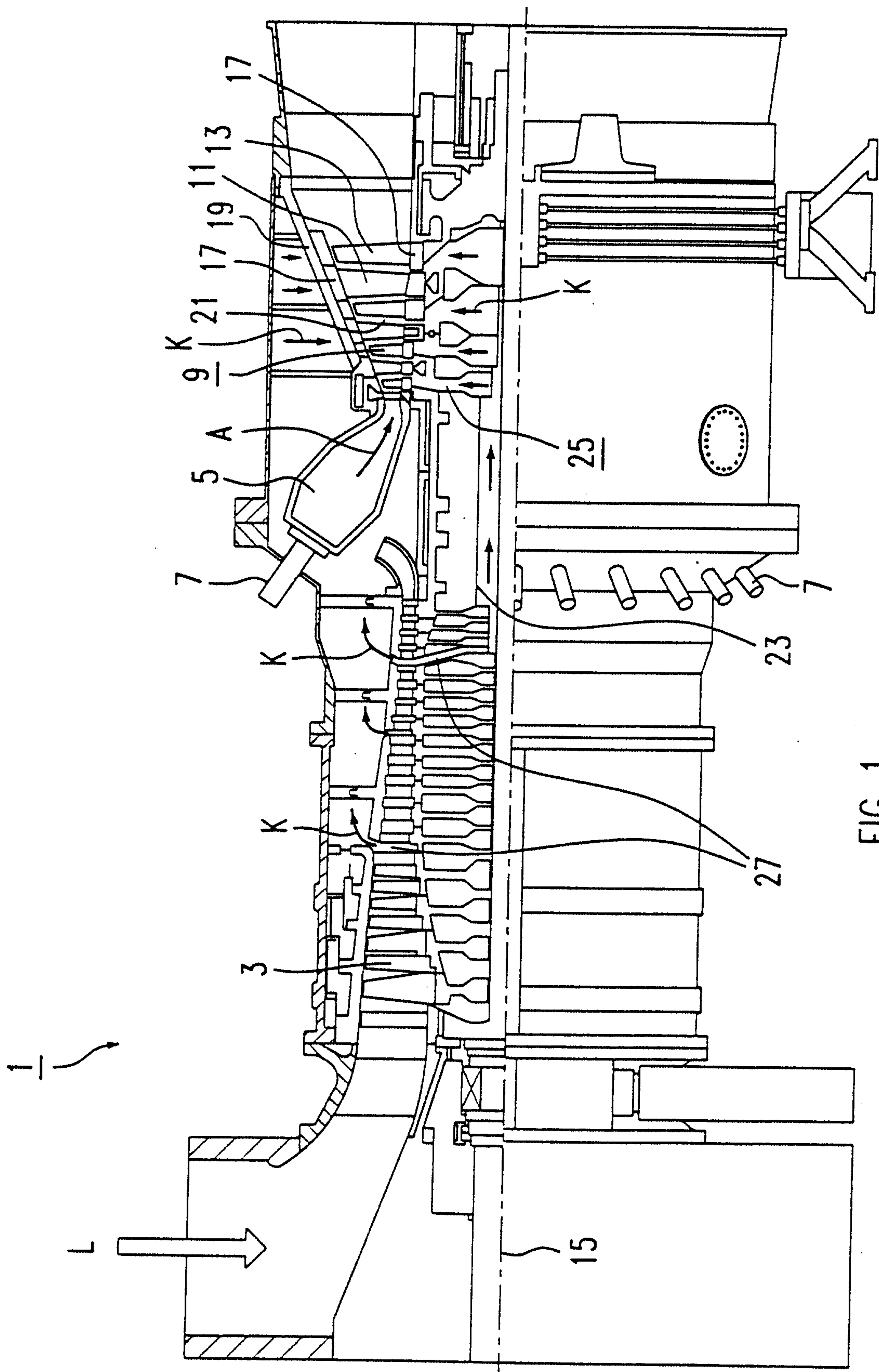
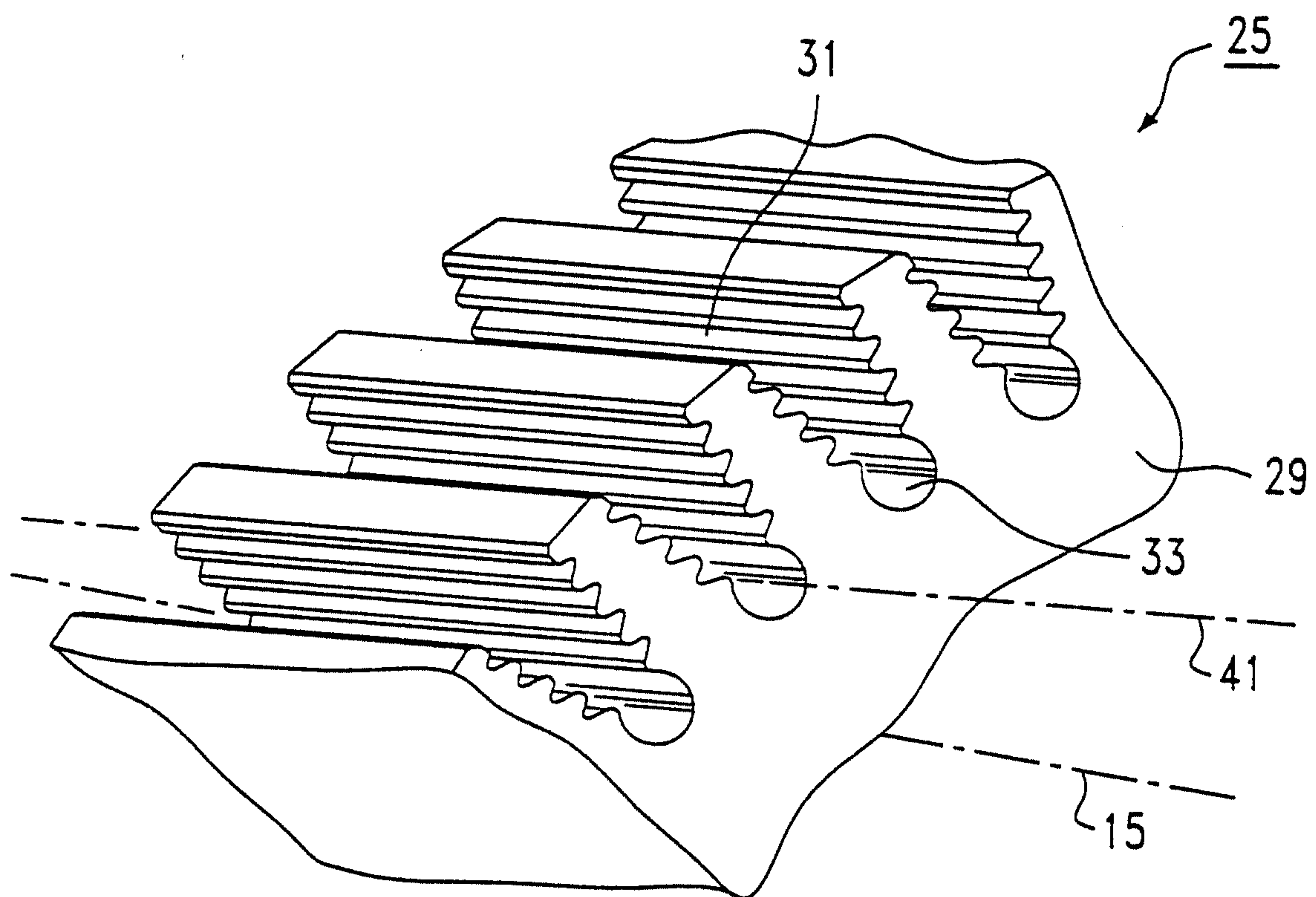
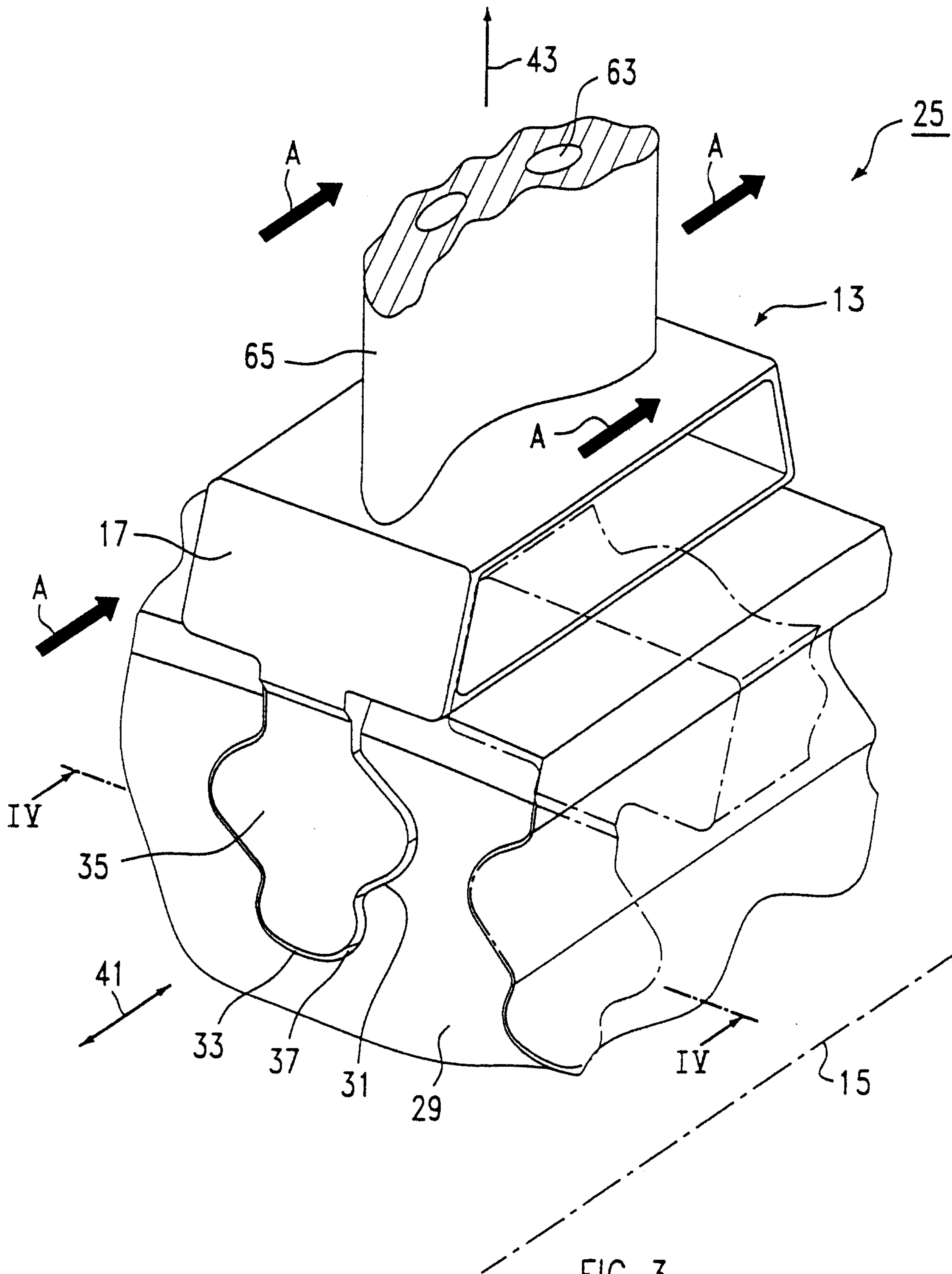


FIG 1

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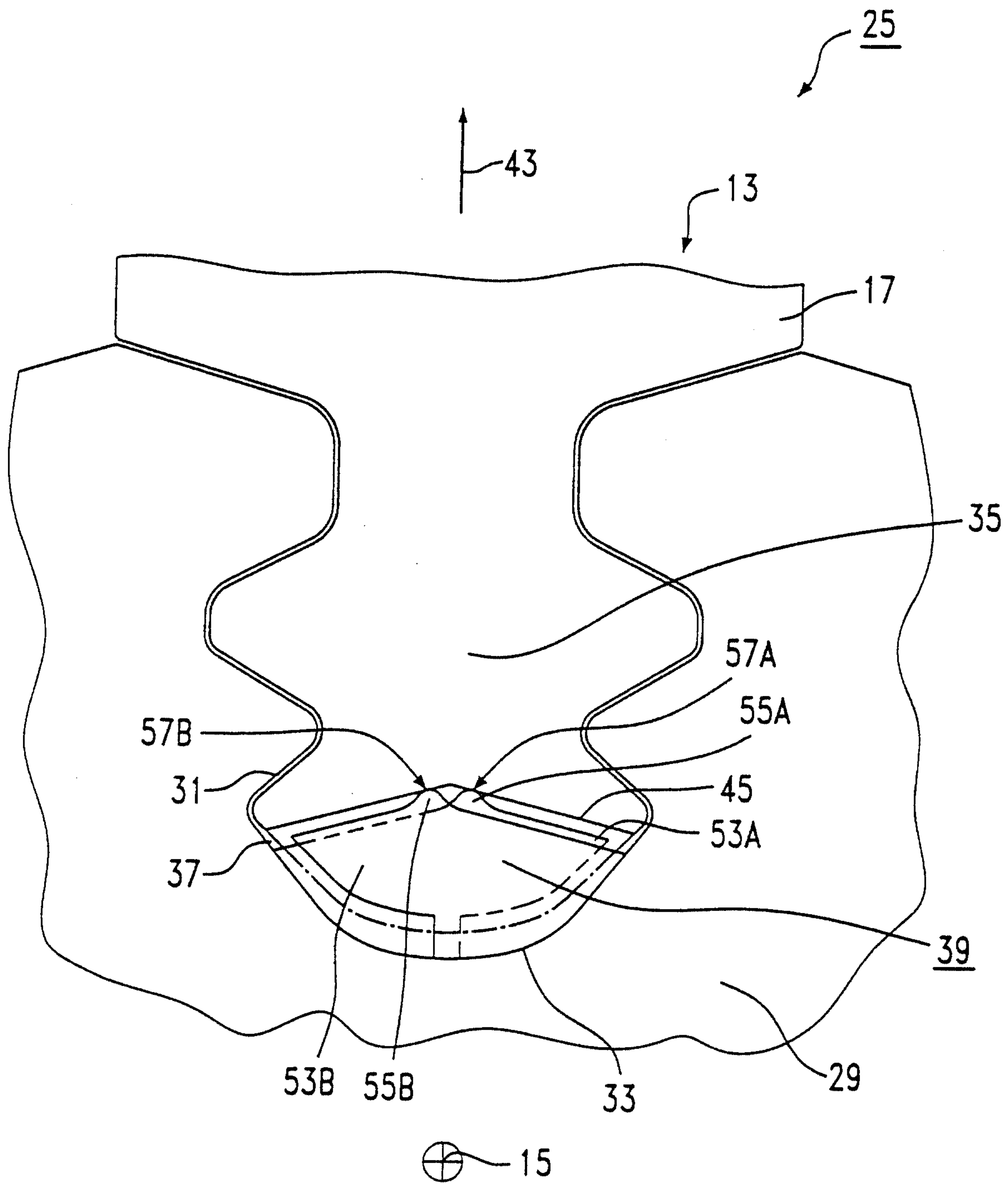


FIG 4

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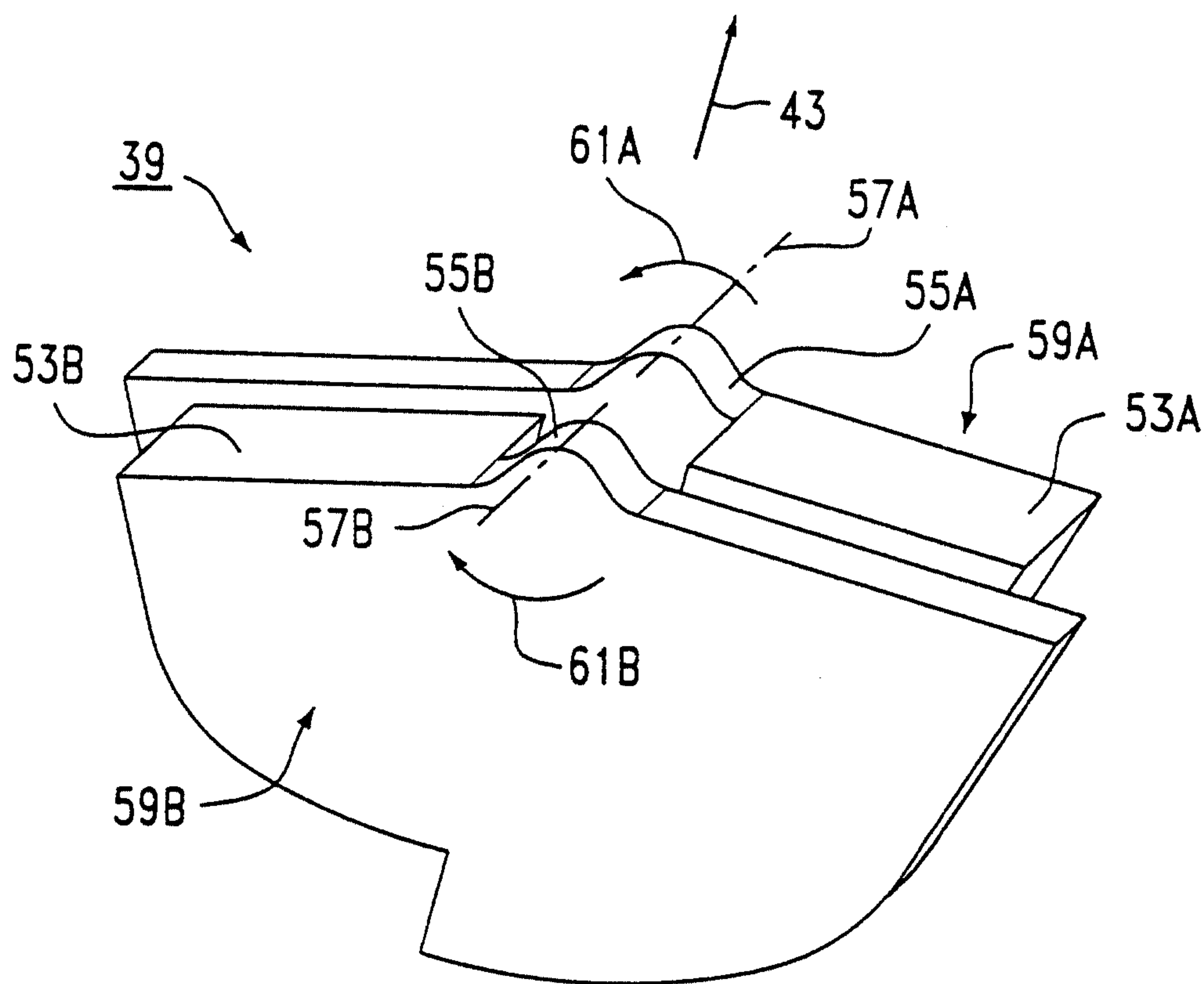


FIG 5

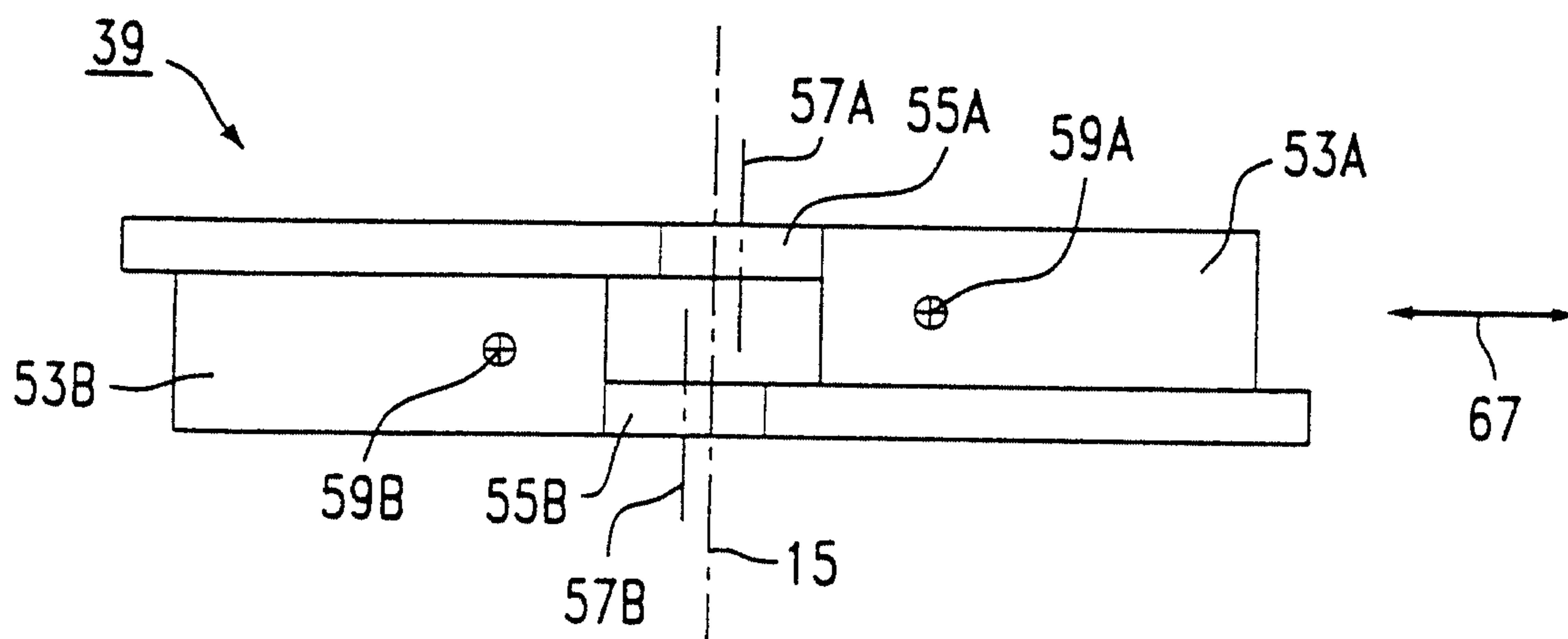
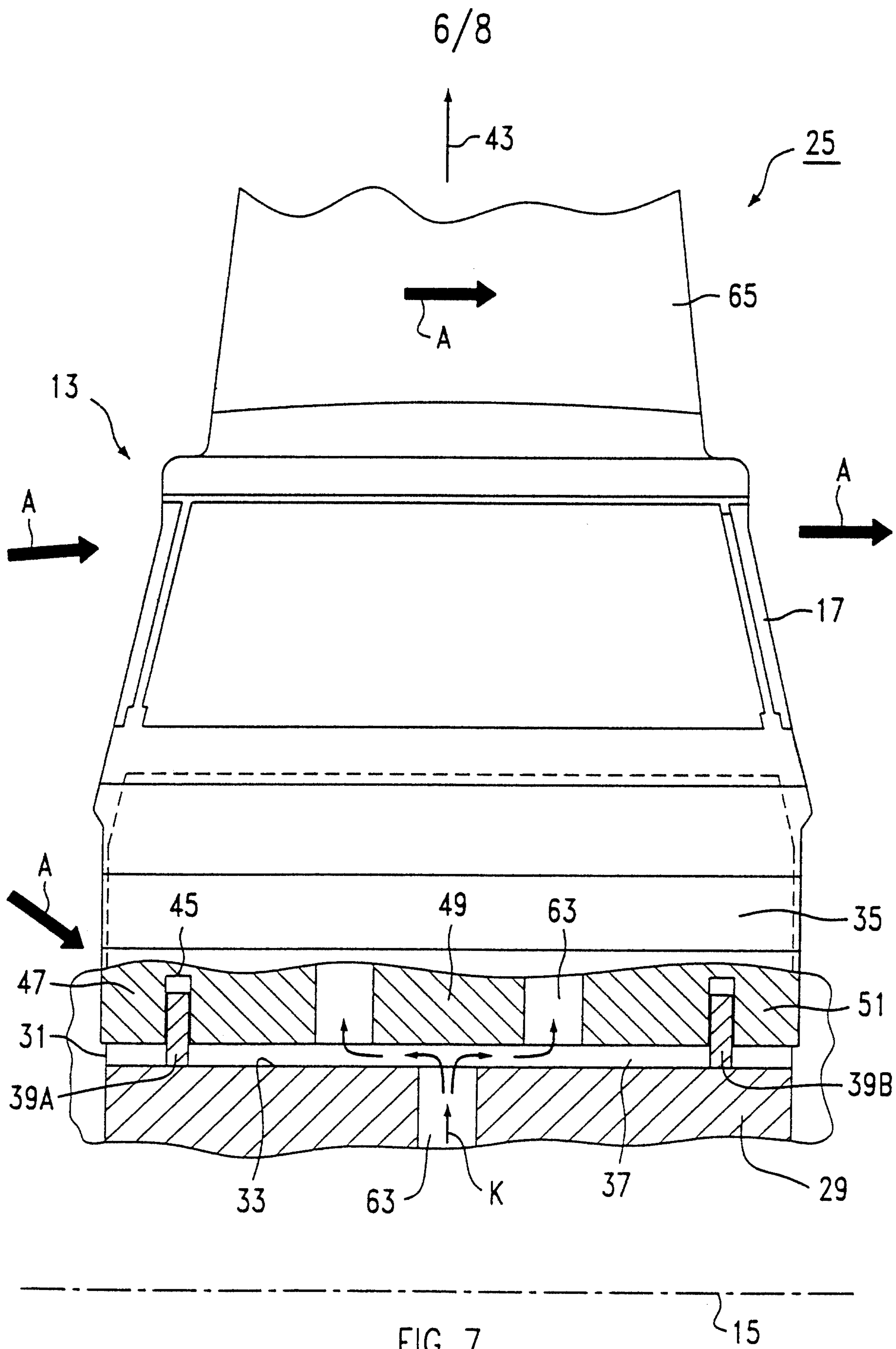
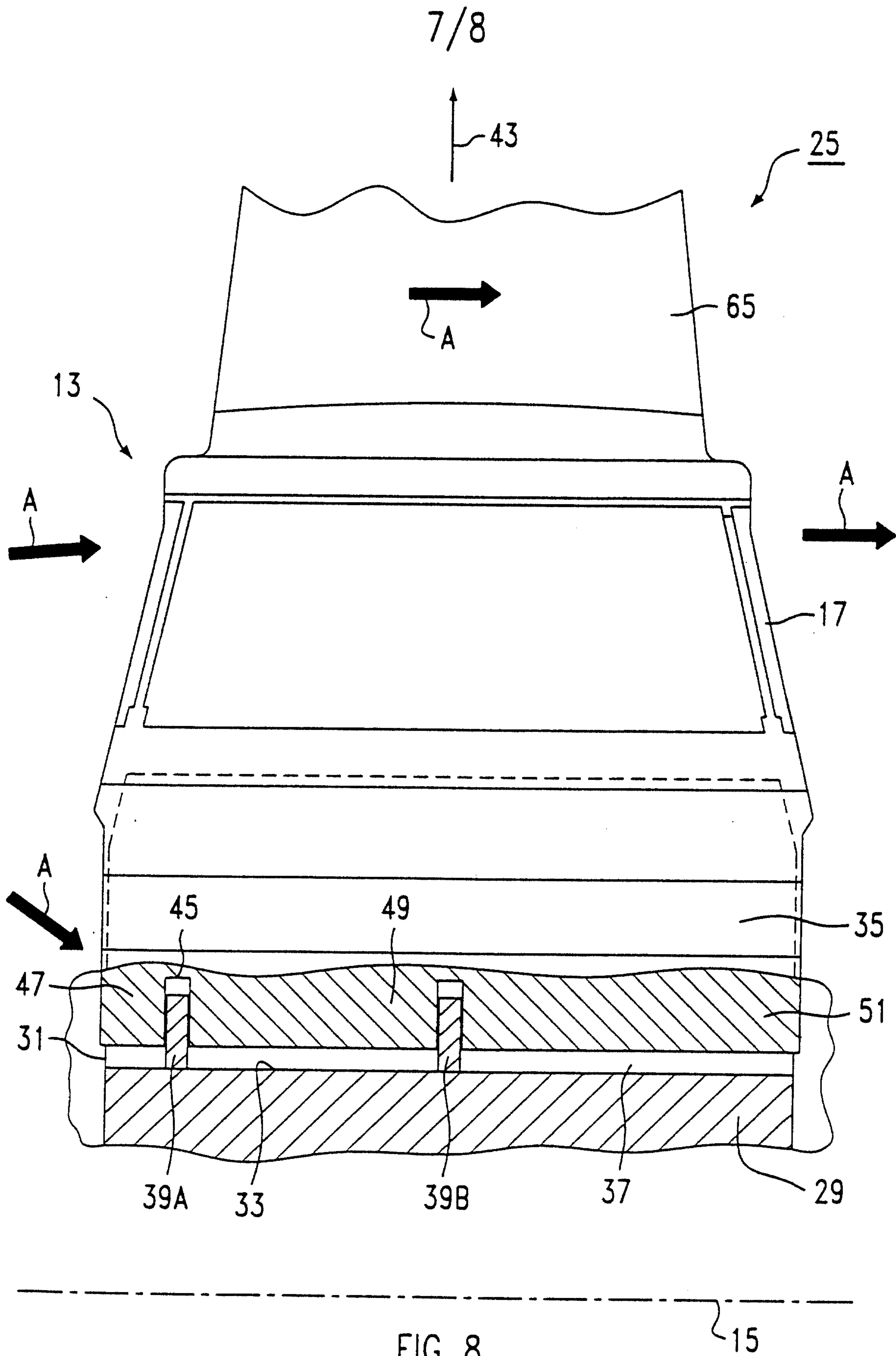


FIG 6





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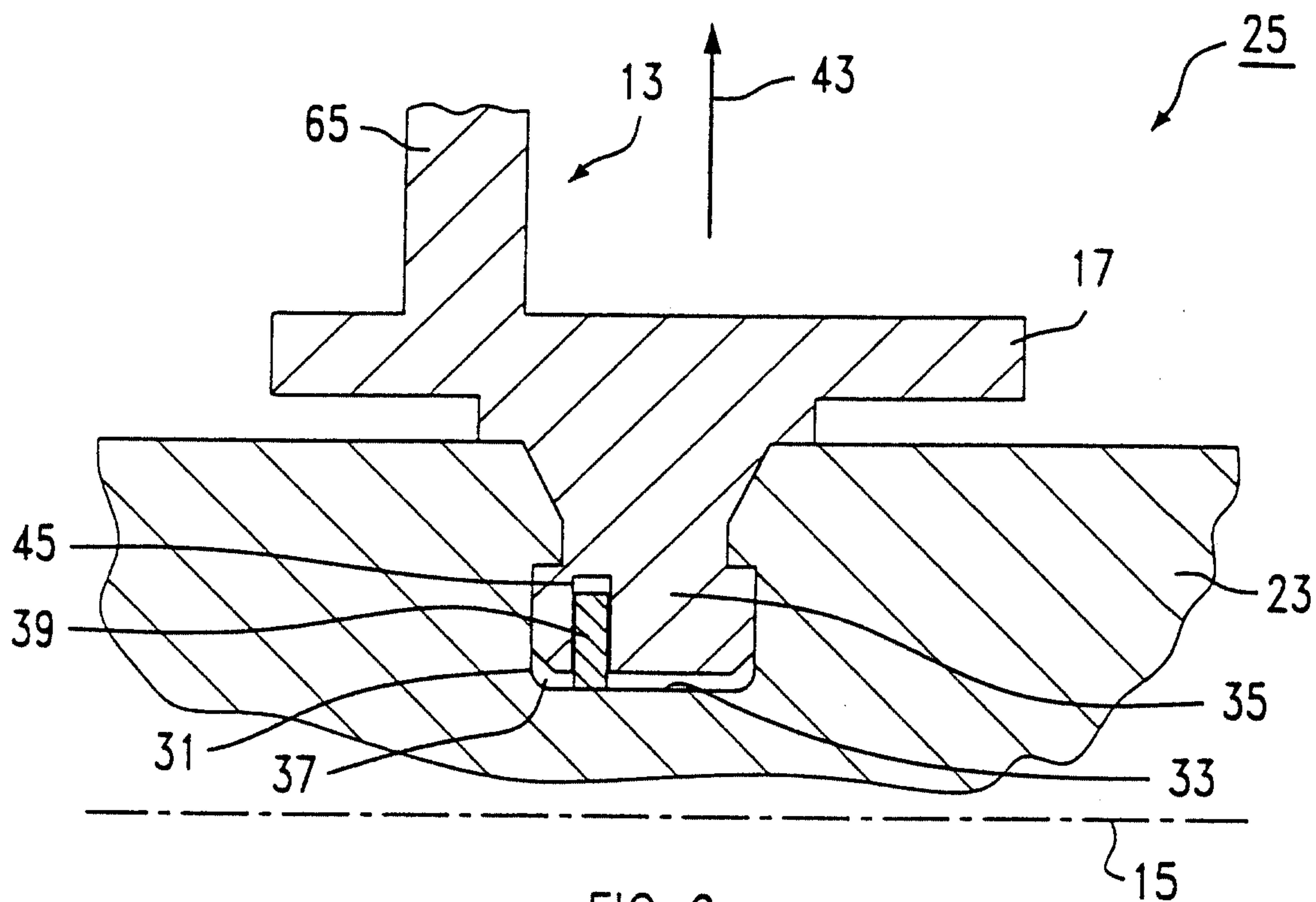


FIG 9

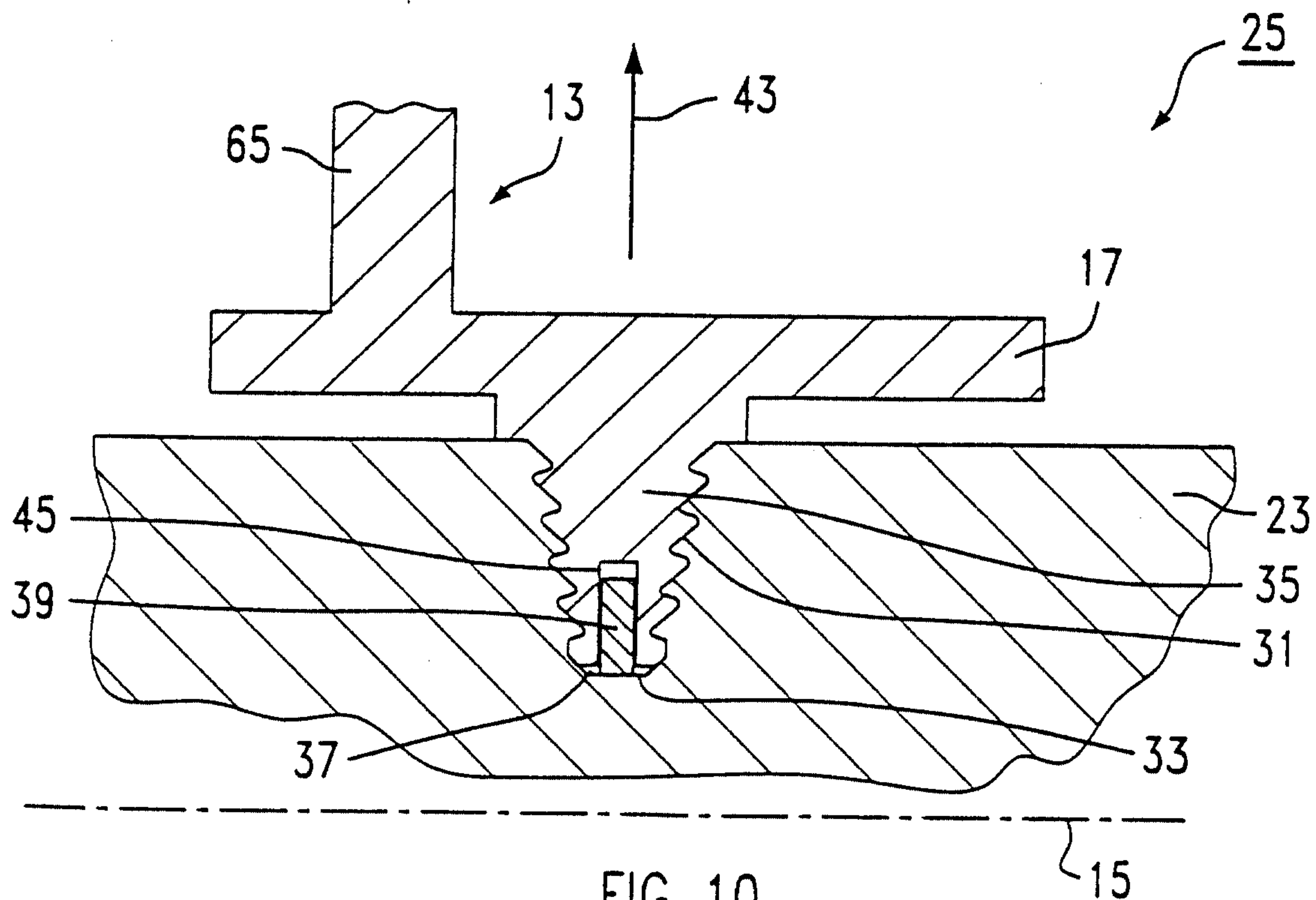


FIG 10

