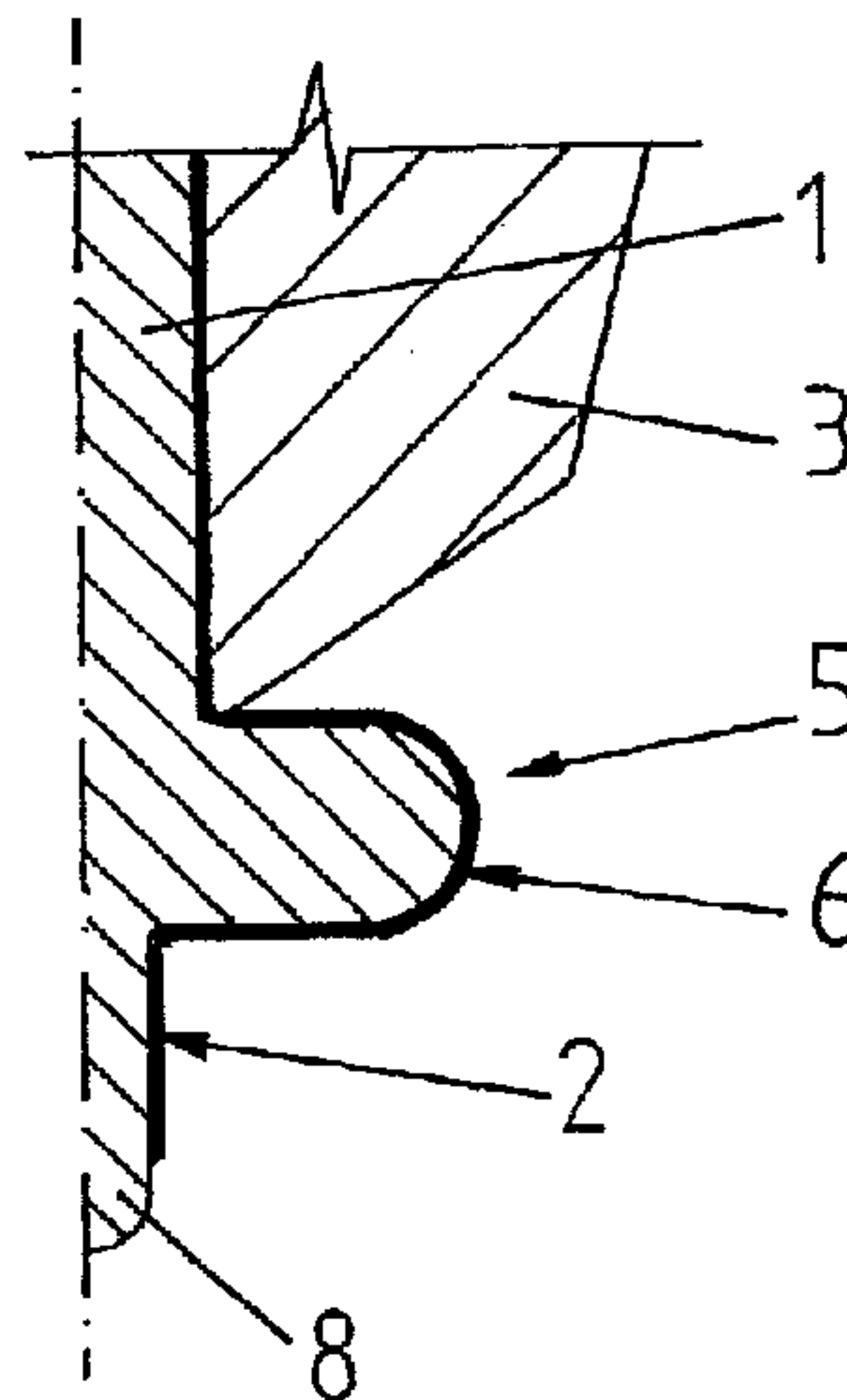




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(54) Titre : PROCÉDE ET DISPOSITIF DE FRAGMENTATION ET/OU D'AFFAIBLISSEMENT DE MATERIAU AU MOYEN D'IMPULSIONS A HAUTE TENSION  
(54) Title: METHOD AND DEVICE FOR FRAGMENTING AND/OR WEAKENING MATERIAL BY MEANS OF HIGH-VOLTAGE PULSES



(57) **Abrégé/Abstract:**

The invention relates to a method for fragmenting and/or weakening material by means of high-voltage pulses, the material and a processing fluid being arranged in a processing zone formed between two electrodes such that the entire processing zone is flooded with processing fluid, and high-voltage pulses being applied to the electrodes such that high-voltage breakdowns occur between the two electrodes and/or such that predischage channels are formed without breakdowns. An electrode with a metallic conductor (1) is chosen for at least one of the two electrodes, the conductor being provided partially or completely with an insulator or insulating coating (2) at the working end of the electrode that is in contact with the processing fluid, the permittivity of the insulator/insulating coating being at least 75% of the permittivity of the processing fluid. The use of such an electrode allows the energy efficiency of methods for fragmenting and/or weakening material by means of high-voltage pulses to be significantly improved and further allows greater tolerance to be achieved with respect to an increase in the conductivity of the processing fluid.

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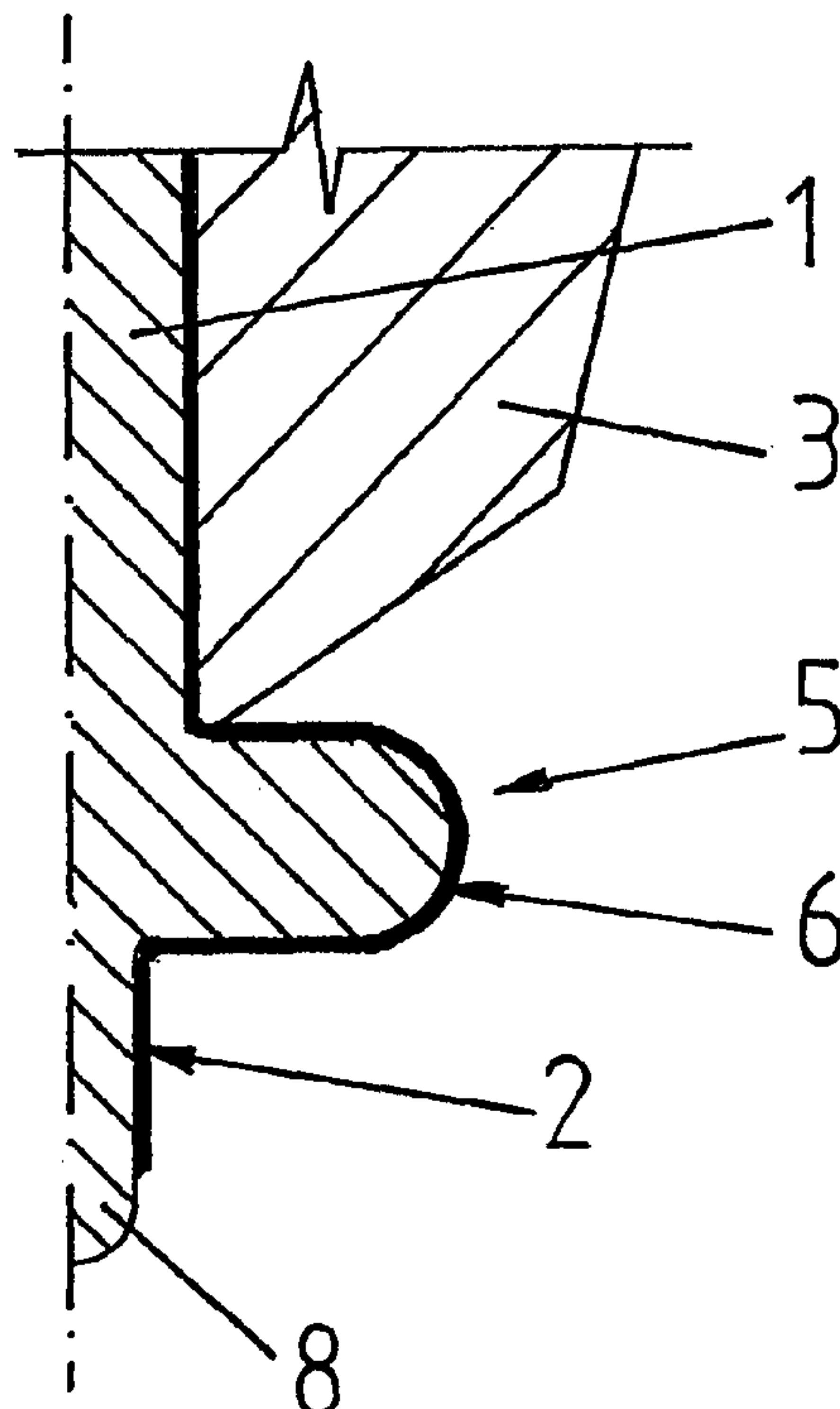
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(54) Title: METHOD AND DEVICE FOR FRAGMENTING AND/OR WEAKENING MATERIAL BY MEANS OF HIGH-VOLTAGE PULSES

(54) Bezeichnung : VERFAHREN UND VORRICHTUNG ZUR FRAGMENTIERUNG UND/ODER SCHWÄCHUNG VON MATERIAL MITTELS HOCHSPANNUNGSPULSEN

Fig. 2



(57) Abstract: The invention relates to a method for fragmenting and/or weakening material by means of high-voltage pulses, the material and a processing fluid being arranged in a processing zone formed between two electrodes such that the entire processing zone is flooded with processing fluid, and high-voltage pulses being applied to the electrodes such that high-voltage breakdowns occur between the two electrodes and/or such that predischarged channels are formed without breakdowns. An electrode with a metallic conductor (1) is chosen for at least one of the two electrodes, the conductor being provided partially or completely with an insulator or insulating coating (2) at the working end of the electrode that is in contact with the processing fluid, the permittivity of the insulator/insulating coating being at least 75% of the permittivity of the processing fluid. The use of such an electrode allows the energy efficiency of methods for fragmenting and/or weakening material by means of high-voltage pulses to be significantly improved and further allows greater tolerance to be achieved with respect to an increase in the conductivity of the processing fluid.

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Die Erfindung betrifft ein Verfahren zur Fragmentierung und/oder Schwächung von Material mittels Hochspannungspulsen, wobei das Material und eine Prozessflüssigkeit in einer zwischen zwei Elektroden gebildeten Prozesszone angeordnet werden, derart, dass die gesamte Prozesszone mit Prozessflüssigkeit geflutet ist, und wobei die Elektroden mit Hochspannungspulsen beaufschlagt werden, derart, dass es zwischen den beiden Elektroden zu Hochspannungsdurchschlägen kommt und/oder zur Bildung von Vorentladungskanälen ohne Durchschläge. Für mindestens eine der beiden Elektroden wird eine Elektrode mit einem metallischen Leiter (1) gewählt, der am Arbeitsende der Elektrode, welches mit der Prozessflüssigkeit in Kontakt steht, teilweise oder vollständig mit einer Isolierung oder Isolationsbeschichtung (2) versehen ist, welche eine Permittivität aufweist, die mindestens 75% der Permittivität der Prozessflüssigkeit beträgt. Durch die Verwendung einer derartigen Elektrode kann der energetische Wirkungsgrad von Verfahren zur Fragmentierung und/oder Schwächung von Material mittels Hochspannungspulsen deutlich verbessert und zudem eine erhöhte Toleranz bezüglich einer Zunahme der Leitfähigkeit der Prozessflüssigkeit erreicht werden.



**Method and device for fragmenting and/or  
weakening material by means of high-voltage pulses**

Background

5

The invention relates to a method for fragmenting and/or weakening material by means of high-voltage pulses, an electrode for using in the method, a device for fragmenting and/or weakening material by means  
10 of high-voltage pulses particularly according to the method, as well as the use of the electrode or of the device for fragmenting and/or weakening material.

15

Prior art

It is known from the prior art how to fragment or weaken a variety of materials, e.g. concrete or rocks, by means of pulsed high-voltage discharges, e.g. to induce  
20 cracks in such a way that the materials can be fragmented easier in a subsequent mechanical fragmenting process.

In order to do this, the material to be fragmented or weakened, respectively, is inserted together with a processing fluid, e.g. water, into a zone where high  
25 voltage discharges are generated between two electrodes. In order to generate a discharge, the electrodes are supplied with a high-voltage pulse. For this, a limited time interval is required in order for predischARGE channels to overcome the processing fluid and the material  
30 distances and for a continuous plasma channel to build up, which then leads to a discharge. During this time a current flows between the electrodes via the processing fluid, having a certain electrical conductivity which may rise with longer operating times, such that the voltage between  
35 the electrodes continuously decreases as a consequence of the discharge of the energy well providing the energy. The current flowing during this time until the high-voltage

breakdown doesn't provide fragmenting or weakening but only heats up the processing fluid. It therefore means a loss which worsens the energetic efficiency of the process. A permanent replacing or a continuous complex recycling of the processing fluid with the aim of maintaining or reducing the electric conductivity also reduces the efficiency of the process. If the voltage decreases below the breakdown voltage already during the formation of the predischARGE channels, the predischARGE channels don't grow any further and "die" off. A high-voltage breakdown or a continuous plasma channel doesn't occur in this case, and the entire supplied energy is lost for the fragmenting or weakening process, respectively.

In case of certain applications it may be desired to generate only predischARGE channels and no high-voltage breakdowns in order to pre-weaken the material in a gentle manner. In this case it is however also desired that an as small as possible part of the supplied energy serves for heating up the processing fluid and an as large as possible part serves for generating the predischARGE channels.

#### Disclosure of the invention

It is an objective of the invention to provide methods and devices for fragmenting and/or weakening materials by means of high-voltage pulses, which have an as good as possible energetic efficiency and are tolerant with respect to a conductivity increase of the processing fluid.

According to an aspect of the present invention, there is provided a method for fragmenting and/or weakening material, particularly rock material or ore, by means of high-voltage pulses, wherein the material to be fragmented and/or weakened and a processing fluid are arranged in a process zone formed between two electrodes, such that the entire process zone is flooded



with processing fluid, and wherein high-voltage pulses are applied to the electrodes such that high-voltage breakdowns occur between the two electrodes and/or such that predischage channels are formed without breakdowns,

5                wherein an electrode with a metallic conductor is chosen for at least a first of the two electrodes, which conductor is provided partially or completely with a first insulation, particularly a first insulating coating at the working end of the electrode that is in contact with the  
10        processing fluid, the permittivity of the insulation/insulating coating being at least 75% of the permittivity of the processing fluid, which is particularly water.

15                In some embodiments of the present invention, there can be provided the method as described herein, wherein a first electrode is chosen, the first insulation or insulation coating of which has a permittivity above 50, particularly above 80.

20                In some embodiments of the present invention, there can be provided the method as described herein, wherein a first electrode is chosen, the first insulation or insulation coating of which has a permittivity between  
25        60 and 100, particularly between 75 and 85.

                 In some embodiments of the present invention, there can be provided the method as described herein, wherein a first electrode is chosen, having at its working  
30        extremity which is in contact with the processing fluid partially or entirely the first insulation or insulation coating, respectively, and partially a second insulation, particularly a second insulation coating having a permittivity smaller than 50% of the permittivity of the  
35        processing fluid which is in particular water, particularly a permittivity between 2 and 10.

                 In some embodiments of the present invention, there can be provided the method as described herein,  
40        wherein a first electrode is chosen, in case of which the first insulation or insulation coating, respectively, and the second insulation or insulation coating, respectively, are adjacent, are merged or penetrate one another, such

that they form a continuous, particularly closed, insulation surface.

In some embodiments of the present invention,  
5 there can be provided the method as described herein, wherein a first electrode is chosen, in case of which the permittivity of the insulation surface formed by the first insulation or insulation coating, respectively, and the  
10 second insulation or insulation coating, respectively, decreases in a direction away from the working extremity, particularly decreases continuously at least sectionwise.

In some embodiments of the present invention, there can be provided the method as described herein,  
15 wherein the process zone is formed between two electrodes arranged one above the other at a distance from one another, such that the material to be fragmented and/or weakened arranged in the process zone lies on the lower electrode, wherein particularly the first electrode is used  
20 as upper electrode.

In some embodiments of the present invention, there can be provided the method as described herein, wherein a closed process zone, particularly inside a closed  
25 process container, is formed.

In some embodiments of the present invention, there can be provided the method as described herein, wherein an open process zone is formed, particularly  
30 wherein a conveyor electrode is used as the lower electrode.

According to another aspect of the present invention, there is provided an electrode for using in the  
35 method as described herein comprising a metallic conductor having on its working extremity of the electrode, which is in contact with the processing fluid when the electrode is used as intended, partially or entirely a first insulation, particularly a first insulation coating, having a  
40 permittivity higher than 50, particularly higher than 80.

In some embodiments of the present invention, there can be provided the electrode as described herein,



wherein the permittivity of the first insulation or insulation coating, respectively, is between 60 and 100, particularly between 75 and 85.

5           In some embodiments of the present invention, there can be provided the electrode as described herein, wherein the metallic conductor has at the working extremity of the electrode, which is in contact with the processing fluid when the electrode is used as intended, partially a  
10 second insulation, particularly a second insulation coating, having a permittivity smaller than 50, particularly a permittivity between 2 and 10.

          In some embodiments of the present invention,  
15 there can be provided the electrode as described herein, wherein the first insulation or insulation coating, respectively, and the second insulation or insulation coating, respectively, are adjacent, are merged or penetrate one another, such that they form a continuous,  
20 particularly closed, insulation surface.

          In some embodiments of the present invention, there can be provided the electrode as described herein, wherein the permittivity of the insulation surface formed  
25 by the first insulation or insulation coating, respectively, and the second insulation or insulation coating, respectively, decreases in a direction away from the working extremity, particularly decreases continuously at least sectionwise.

30           In some embodiments of the present invention, there can be provided the electrode as described herein, wherein the metallic conductor of the electrode forms an annular section with rounded edge at the working extremity.

35           In some embodiments of the present invention, there can be provided the electrode as described herein, wherein the annular section is separated from the metallic conductor by the first insulation or insulation coating,  
40 respectively.

          In some embodiments of the present invention, there can be provided the electrode as described herein,



wherein the annular section has the first insulation or insulation coating, respectively, at least on its surfaces showing away from the working extremity.

5           In some embodiments of the present invention, there can be provided the electrode as described herein, wherein the annular section forms the working side extremity of the electrode.

10           In some embodiments of the present invention, there can be provided the electrode as described herein, wherein a particularly spherical segment-shaped or paraboloid-of-revolution-shaped electrode tip follows the annular section, the electrode tip forming the working  
15 extremity of the electrode and is particularly matallically blank at its free end.

          In some embodiments of the present invention, there can be provided the electrode as described herein,  
20 wherein the electrode has a insulating body made of a material with a permittivity smaller than 20, out of which the metallic conductor protrudes at the working extremity.

          In some embodiments of the present invention, there can be provided the electrode as described herein,  
25 wherein the insulating body is interspersed with one or more annular elements, which are concentric to the metallic conductor penetrating the insulating body and made of a material with a higher permittivity than the material of  
30 the isolator.

          In some embodiments of the present invention, there can be provided the electrode as described herein, wherein the metallic conductor has the first or the second  
35 insulation or insulation coating, respectively, in the section where it protrudes out of the insulating body.

          According to another aspect of the present invention, there is provided a device for fragmenting  
40 and/or weakening material, particularly rock material or ore, by means of high-voltage pulses, particularly for carrying out the method as described herein, with two electrodes of which at least one is formed as an electrode

as described herein, wherein a process zone is formed between the two electrodes, in which the material to be fragmented and/or weakened and a processing fluid can be arranged such that the entire process zone is flooded with  
5 processing fluid, and wherein high-voltage pulses are applied to the electrodes such that high-voltage breakdowns occur between the two electrodes and/or such that predischARGE channels are formed without breakdowns.

10 In some embodiments of the present invention, there can be provided the device as described herein, wherein each of the two electrodes is formed as electrode as described herein.

15 In some embodiments of the present invention, there can be provided the device as described herein, wherein the two electrodes are arranged one above the other in such a way that the material to be fragmented and/or weakened lies on the lower electrode when the process zone  
20 is flooded, and particularly wherein at least the upper electrode is formed as described herein.

In some embodiments of the present invention, there can be provided the device as described herein,  
25 wherein the process zone is formed in a particularly closed container.

In some embodiments of the present invention, there can be provided the device as described herein,  
30 wherein the process zone is formed as opened process zone and particularly wherein both electrodes are arranged above one another and the lower electrode is formed as conveyor electrode.

35 According to another aspect of the present invention, there is provided a use of the electrode as described herein or of the device as described herein for fragmenting and/or weakening material, particularly rock material or ore, by means of high-voltage pulses,  
40 particularly for carrying out the method as described herein.



A first aspect of the invention relates to a method for fragmenting and/or weakening material, preferably rock material or ore, by means of high-voltage pulses.

Fragmenting means crushing the material. Weakening (also called pre-weakening) means generating internal cracks in the material, thereby simplifying a further, particularly mechanical, crushing of the material.

The material to be fragmented and/or weakened and a processing fluid are arranged in an opened or closed process zone formed between two electrodes, such that the entire process zone is flooded with processing fluid and therefore both electrodes are in contact with the processing fluid and the material to be fragmented or weakened arranged between the electrodes is entirely immersed into the processing fluid. In this state the electrodes are supplied with high-voltage pulses such that high-voltage breakdowns occur between them, or only such that predischARGE channels are formed, without breakdowns, e.g. when the latter are not desired.

According to the invention at least one of the two electrodes is an electrode according to the invention, having a metallic conductor arranged at the working extremity of the electrode that is in contact with the processing fluid, the conductor being provided partially or completely with an insulator or insulating coating according to the invention, the permittivity of which amounts to at least 75% of the permittivity of the processing fluid. Preferably, water is used as processing fluid, typically having a permittivity of about 80.

Surprisingly it has been noticed that the use of such an electrode according to the invention makes it possible to significantly improve the energetic efficiency of methods of this kind for fragmenting and/or weakening material by means of high-voltage pulses and additionally a higher tolerance with respect to an increase of the conductivity of the processing fluid can be achieved.

Preferably an electrode according to the invention is used, the first insulation or insulation



coating of which has a permittivity above 50, preferably above 80.

It is further preferred that the permittivity of the first insulation or insulation coating is between  
5 60 and 100, particularly between 75 and 85.

Use of electrodes with such first insulations or insulation coatings, respectively, is particularly advantageous in methods using water as processing fluid.

In a preferred embodiment of the method a first  
10 electrode according to the invention is used, wherein its metallic conductor at the working extremity of the electrode which is in contact with the processing fluid has, additionally to the first insulation or insulation coating according to the invention, a second insulation or  
15 insulation coating having a permittivity smaller than 50% of the permittivity of the processing fluid, particularly a permittivity between 2 and 10. Sections of the electrode which have this second insulation or insulation coating, respectively, are particularly appropriate for  
20 mechanically connecting the electrode to a supporting structure.

It is preferred that a first electrode according to the invention is used, in case of which the first insulation or insulation coating, respectively, and  
25 the second insulation or insulation coating, respectively, are adjacent, are merged or penetrate one another, such that they form a continuous and preferably closed insulation surface. In this way it is possible to place regions with very high electric fields in those zones of  
30 the respective electrode contour, where they are desired for generating predischARGE channels and, if necessary, high-voltage breakdowns.

Furthermore it is preferred that the permittivity of the insulation surface formed by the first  
35 insulation or insulation coating, respectively, and the second insulation or insulation coating, respectively, decreases in a direction away from the working extremity,

such that the insulation surface has the highest permittivity in the area which is closest to the free end of the working extremity, and has the lowest permittivity in the area situated farthest from this free end. It is preferred that the decrease of permittivity is continuous, at least sectionwise. This can e.g. be reached in such a way that the insulations or insulation coatings, respectively, penetrate one another or are merged in a certain area. In this way it is possible to avoid abrupt field changes.

In a further preferred embodiment of the method the process zone is formed between two electrodes arranged one above the other at a distance from one another, such that the material to be fragmented and/or weakened arranged in the process zone lies on the lower electrode. At least as upper electrode preferably is a first electrode according to the invention. Such an electrode arrangement has been found to be particularly advantageous and additionally offers the advantage, when the upper electrode is formed as the first electrode according to the invention, that its first and/or second insulation or insulation coating is only worn to a small extent by the material to be fragmented and/or weakened.

In further preferred embodiments the method is carried out in a closed process zone, preferably inside a closed process container, or in an open process zone. The first variant is particularly appropriate for a batch operation while the second variant is preferred in case of a continuous operation mode. In the second case a conveyor electrode is used as the lower electrode, by means of which the material to be fragmented and/or weakened is guided into the process zone and can be removed from the process zone after having acted upon it.

A second aspect of the invention relates to an electrode for using in the method according to the first aspect of the invention.



The electrode comprises a metallic conductor, e.g. made of copper or stainless steel, having on the working extremity of the electrode, i.e. at the extremity of the electrode, which is in contact with the processing fluid when the electrode is used as intended, partially or  
5 entirely a first insulation or insulation coating according to the invention. This first insulation or insulation coating has a permittivity higher than 50, preferably higher than 80.

10 By using such electrodes according to the invention it is possible to significantly improve the energetic efficiency of methods of this kind for fragmenting and/or weakening material by means of high-voltage pulses and additionally to achieve a higher  
15 tolerance with respect to an increase of the conductivity of the processing fluid.

The first insulation or insulation coating according to the invention has a permittivity between 60 and 100, more preferred between 75 and 85. Electrodes with  
20 such first insulations or insulation coatings, respectively, are particularly advantageous in methods using water as processing fluid.

In a preferred embodiment of the electrode, its metallic conductor has at the working extremity of the  
25 electrode additionally to the first insulation or insulation coating according to the invention a second insulation or insulation coating according to the invention, having a permittivity smaller than 50, particularly a permittivity between 2 and 10. Areas having  
30 this second insulation or insulation coating, respectively, are particularly appropriate for mechanically connecting the electrode to a supporting structure.

It is therefore preferred that the first  
35 insulation or insulation coating, respectively, and the second insulation or insulation coating, respectively, according to the invention, are adjacent, are merged or

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penetrate one another, such that they form a continuous, advantageously closed, insulation surface. In this way it is possible to avoid possible discharge zones between the insulations or insulation coatings respectively.

5 In case of this embodiment it is preferred that the permittivity of the insulation surface formed by the first insulation or insulation coating, respectively, and the second insulation or insulation coating, respectively, decreases in a direction away from the working extremity, such that the insulation surface has the highest  
10 permittivity in the area which is closest to the free end of the working extremity, and has the lowest permittivity in the area situated farthest from this free end. It is preferred that the decrease of permittivity is continuous, at least sectionwise. In this way it is possible to avoid  
15 abrupt field changes.

In yet a further preferred embodiment of the electrode the metallic conductor forms an annular section with rounded edge at the working extremity. This annular  
20 area serves as field relief when the electrode is used as intended.

The annular section may be connected to the metallic conductor in an electrically conducting way, e.g. when it is in one piece with it, or it may be separated  
25 from the metallic conductor by the first insulation or insulation coating, respectively, and therefore electrically insulated from it. The function as field relief is insignificantly influenced by this.

Advantageously the annular section has the first insulation or insulation coating, respectively, at  
30 least on its surfaces showing away from the working extremity, particularly when it is connected to the metallic conductor in an electrically conducting way. In this way it is possible to significantly diminish the electrically conducting surface of the electrode.  
35

In a variant of the electrode described above the annular section forms the working side extremity of



the electrode. In this way a blunt electrode with a large, e.g. plate-shaped, front face is obtained.

In another variant of the electrode a particularly spherical segment-shaped or paraboloid-of-revolution-shaped electrode tip follows the annular section, the electrode tip forming the working extremity of the electrode. Preferably, this electrode tip is metallically blank at its free end. In this way a relatively sharp electrode with a small front face is  
10 obtained.

Depending on the field of use of the electrode the one or the other variant is preferred.

In yet another preferred embodiment the electrode has an insulating body made of a material with a permittivity smaller than 20, e.g. PE or PP, out of which  
15 the metallic conductor protrudes at the working extremity. This insulating body may form a second insulation or may be present in addition to another second insulation or insulation coating. Such electrodes may be attached to a supporting structure in an electrically insulated way by  
20 means of the insulating body in a simple way.

In a variant of this embodiment of the electrode, the insulating body is interspersed with one or  
25 more annular elements, which are concentric to the metallic conductor penetrating the insulating body and made of a material with a higher permittivity than the material of the isolator, e.g. a metallic material like stainless steel, or a plastic interspersed with graphite. In this  
30 way the permittivity distribution, which is averaged in this section with respect to the volume of the insulating body, may be influenced in a targeted way.

Furthermore, in case of the embodiment of the electrode with one insulating body, it is preferred that  
35 the metallic conductor has the first or the second insulation or insulation coating, respectively, in the section where it protrudes out of the insulating body.

Particularly in case that it has the second insulation or insulation coating at this position, a relatively smooth transition with respect to the electric field strengths from the insulating body to the metallic body is reached.

5           A third aspect of the invention relates to a device for fragmenting and/or weakening material, particularly rock material or ore, by means of high-voltage pulses. This embodiment is advantageously suitable for carrying out the method according to the first aspect of  
10 the invention.

          The device comprises two electrodes of which one or both is or are formed according to the second aspect of the invention. A process zone is formed between the two electrodes, in which the material to be fragmented and/or  
15 weakened and a processing fluid can be arranged such that the entire process zone is flooded with processing fluid. In this state high-voltage pulses being applied to the electrodes such that high-voltage breakdowns occur between the two electrodes and/or such that predischARGE channels  
20 are formed without breakdowns.

          In a preferred embodiment of the device both electrodes are arranged one above the other in such a way that the material to be fragmented and/or weakened lies on the lower electrode when the process zone is flooded.  
25 Advantageously at least the upper electrode is formed according to the second aspect of the invention. Such an arrangement of the electrodes has been found to be particularly advantageous and offers additionally the advantage, when the upper electrode is formed as first  
30 electrode, that its first and/or second insulation or insulation coating, respectively, is only little stressed by the material to be fragmented and/or weakened.

          In further preferred embodiments the device has  
35 either a closed or closable, respectively, process zone, which is preferably formed by a closed process container, or an opened process zone. The first variant is

-10-

particularly suitable for a batch operation mode, while the last variant is preferred in case of a continuous operation. In the last case the lower electrode is preferably formed as a conveyor electrode, by means of which the material to be fragmented and/or weakened is guided into the process zone and may be removed from the process zone after having acted upon it.

#### Short description of the drawings

10

Further embodiments, advantages and applications of the invention result from the dependent claims and from the now following description by means of the figures. Thereby it is shown in:

15

Fig. 1 a vertical section view through a half of the working extremity of a first electrode according to the invention;

20

Fig. 2 a vertical section view through a half of the working extremity of a second electrode according to the invention;

Fig. 3 a vertical section view through a half of the working extremity of a third electrode according to the invention;

25

Fig. 4 a vertical section view through a half of the working extremity of a fourth electrode according to the invention;

Fig. 5 a vertical section view through a half of the working extremity of a fifth electrode according to the invention;

30

Fig. 6 a vertical section view through a half of the working extremity of a sixth electrode according to the invention;

35

Fig. 7 a vertical section view through a half of the working extremity of a seventh electrode according to the invention;



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Fig. 8 a vertical section view through a half of the working extremity of an eighth electrode according to the invention;

Fig. 9 a vertical section view through a half of the working extremity of a ninth electrode according to the invention;

Fig. 10 a vertical section view through a half of the working extremity of a tenth electrode according to the invention;

Fig. 11 a vertical section view through a half of the working extremity of an eleventh electrode according to the invention;

Fig. 12 a vertical section view through a half of the working extremity of a twelfth electrode according to the invention;

Fig. 13 a vertical section view through a half of the working extremity of a thirteenth electrode according to the invention;

Fig. 14 a vertical section view in transversal direction through a half of the working extremity of a fourteenth electrode according to the invention;

Fig. 15 a vertical section view in longitudinal direction through a half of the working extremity of the electrode according to Fig. 14;

Fig. 16 a vertical section view in longitudinal direction through a half of the working extremity of a fifteenth electrode according to the invention;

Fig. 17 a vertical section view in transversal direction through a half of the working extremity of the electrode according to Fig. 16;

Fig. 18 a vertical section view through a half of the working extremity of a sixteenth electrode according to the invention; and

Fig. 19 a view on a half of the working extremity of the electrode according to Fig. 18;

Ways of carrying out the invention

Fig. 1 shows a vertical section view through a half of the working extremity of a first, rotation symmetric electrode according to the invention. As can be seen, the electrode has a substantially bar-shaped metallic conductor 1, e.g. made of copper or stainless steel, which forms an annular section 5 with rounded edge 6 at the shown working extremity of the electrode, and, following the annular section 5 towards the free end of the electrode, a spherical segment-shaped electrode tip 8 which represents the working extremity of the electrode. Except for the actual electrode tip 8, the metallic conductor 1 has a first insulation coating 2 according to the invention, e.g. made of  $\text{TiO}_2$ , having a permittivity which is higher than 50. The annular section 5 serves as field relief.

Fig. 2 shows a vertical section view through a half of the working extremity of a second electrode according to the invention, which differs from the one of Fig. 1 only in that the metallic conductor 1 protrudes out of an insulating body 3 with a permittivity smaller than 20, e.g. made of PE or PP.

Fig. 3 shows a vertical section view through a half of the working extremity of a third electrode according to the invention which differs from the electrode of Fig. 2 only in that the metallic conductor 1 doesn't have an insulation coating in the section where it is surrounded by the insulating body 3.

Fig. 4 shows a vertical section view through a half of the working extremity of a fourth electrode according to the invention which differs from the one of Fig. 3 only in that the electrode tip 8 has a recess 9 in which the insulation coating 2 ends.

Fig. 5 shows a vertical section view through a half of the working extremity of a fifth electrode according to the invention which differs from the one of Fig. 2 only in that the metallic conductor 1 has a second insulation coating 4 according to the invention, e.g. made

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of PE, having a permittivity smaller than 50, in the section following the annular section 5 on the side which is opposed to the working extremity.

Fig. 6 shows a vertical section view through a half of the working extremity of a sixth electrode according to the invention which differs from the one of Fig. 2 only in that the insulating body 3 is interspersed with a plurality of annular elements 7 which are concentric with respect to the metallic conductor 1 penetrating it, made of a material with a higher permittivity than the material of the isolator 3, e.g. made of stainless steel or of a plastic interspersed with graphite.

Fig. 7 shows a vertical section view through a half of the working extremity of a seventh electrode according to the invention which differs from the ones of Fig. 3 and 4 only in that no electrode tip forming the working extremity of the electrode follows the annular section 5 and in that its front face 10 is entirely covered by the insulation coating 2.

Fig. 8 shows a vertical section view through a half of the working extremity of an eighth electrode according to the invention which differs from the one of Fig. 7 only in that the front face 10 is metallically blank and the insulation coating 2 extends a little into the insulating body 3.

Fig. 9 shows a vertical section view through a half of the working extremity of a ninth electrode according to the invention which differs from the one of Fig. 1 only in that it doesn't have the annular section present in Fig. 1.

Fig. 10 shows a vertical section view through a half of the working extremity of a tenth electrode according to the invention which differs from the one of Fig. 9 only in that the metallic conductor 1 protrudes out of an insulating body 3 made of a material with a permittivity smaller than 20, e.g. PE or PP.



Fig. 11 shows a vertical section view through a half of the working extremity of an eleventh electrode according to the invention which differs from the one of Fig. 9 only in that the metallic conductor 1 has the first insulation coating 2 according to the invention only in the section of the electrode tip 8, wherein the electrode tip 8 itself is metallically blank, and has in the other sections a second insulation coating 4 according to the invention, e.g. made of PE, with a permittivity smaller than 50. The two insulation coatings 2, 4 penetrate one another in a transitional area 11.

Fig. 12 shows a vertical section view through a half of the working extremity of a twelfth electrode according to the invention which differs from the one of Fig. 11 only in that the metallic conductor 1 protrudes out of an insulating body 3 made of a material with a permittivity smaller than 20, e.g. PE or PP.

Fig. 13 shows a vertical section view through a half of the working extremity of a thirteenth electrode according to the invention which differs from the one of Fig. 10 only in that the metallic conductor 1 carries an annular bead 5 with rounded edge 6 between the electrode tip 8 and the insulation body 3, made of the same metal like the metallic conductor 1 or of another metallic material which serves as field relief and which is separated from the metallic conductor 1 by the first insulation coating 2 according to the invention and is electrically insulated with respect to the metallic conductor. A further difference to the electrode of Fig. 10 is that the electrode tip 8 is entirely metallically blank. The metallic conductor 1 of such an electrode may be manufactured in a cost efficient way of a round metal bar having the first insulation coating according to the invention, by removing its end for making the blank electrode tip 8 and by shrinking a component 12 forming the annular bead 5 onto the coated metal bar in the section following the electrode tip 8.

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Fig. 14 and 15 show vertical section views in transversal direction (Fig. 14) and in longitudinal direction (Fig. 15) through a half of the working extremity of a fourteenth electrode according to the invention and  
5 differ from the one of Fig. 7 only in that it has a bar-shaped electrode head 13 with rounded edge 6 instead of the round plate-shaped electrode head of the electrode shown in Fig. 7.

Fig. 16 and 17 show a vertical section views  
10 in transversal direction (Fig. 17) and in longitudinal direction (Fig. 16) through a half of the working extremity of a fifteenth electrode according to the invention and differ from the ones of Fig. 14 and 15 only in that it has a yoke-shaped electrode head 14 entirely covered with an  
15 insulation coating 2 according to the invention and between which a blank electrode wire 15 is spanned, instead of the bar-shaped electrode head.

Fig. 18 shows a vertical section view through a half of the working extremity of a sixteenth electrode according to the invention which differs from the one of  
20 Fig. 7 only in that it has a round and plate-shaped electrode head 16 with an edge 17 forming a truncated cone contour instead of the round plate-shaped electrode head of Fig. 7, wherein six finger-shaped electrode tips 18  
25 protrude downwards, being slightly inclined towards the exterior and arranged on the bottom side of the electrode head 16 in the edge region and distributed evenly over the circumference of the same. The electrode tips 18 have spherical segment-shaped front faces. The entire electrode  
30 head 16 has a first insulation coating 2 according to the invention except on the front faces.

Fig. 19 shows a view on a half of the working extremity of the electrode according to Fig. 18.

While preferred embodiments of the invention  
35 are described in the present patent application, it is clearly noted that the invention is not limited to these

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embodiments but can also be carried out in different ways within the scope of the following claims.



The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method for fragmenting and/or weakening material by means of high-voltage pulses, wherein the material to be fragmented and/or weakened and a processing fluid are arranged in a process zone formed between two electrodes, such that the entire process zone is flooded with the processing fluid, and wherein the high-voltage pulses are applied to the electrodes such that high-voltage breakdowns occur between the two electrodes and/or such that predischARGE channels are formed without breakdowns,

wherein an electrode with a metallic conductor is chosen for at least a first of the two electrodes, which conductor is provided partially or completely with a first insulation at a working end of the electrode that is in contact with the processing fluid, the permittivity of the insulation being at least 75% of the permittivity of the processing fluid.

2. The method according to claim 1, wherein the method is for fragmenting and/or weakening rock material or ore.

3. The method according to claim 1 or claim 2, wherein the processing fluid is water.

4. The method according to any one of claims 1 to 3, wherein a first electrode is chosen, the first insulation of which has a permittivity above 50.

5. The method according to any one of claims 1 to 3, wherein a first electrode is chosen, the first insulation of which has a permittivity above 80.

6. The method according to any one of claims 1 to 3, wherein a first electrode is chosen, the first insulation of which has a permittivity between 60 and 100.

7. The method according to any one of claims 1 to 3, wherein a first electrode is chosen, the first insulation of which has a permittivity between 75 and 85.

8. The method according to any one of claims 1 to 3, wherein a first electrode is chosen, having at its working extremity which is in contact with the processing fluid partially or entirely the first insulation, and partially a second insulation having a permittivity smaller than 50% of the permittivity of the processing fluid.

9. The method according to claim 8, wherein the second insulation has a permittivity between 2 and 10.

10. The method according to claim 8 or claim 9, wherein a first electrode is chosen, in case of which the first insulation and the second insulation are adjacent, are merged or penetrate one another, such that they form a continuous insulation surface.

11. The method according to claim 8 or claim 9, wherein a first electrode is chosen, in case of which the first insulation and the second insulation are adjacent, are merged or penetrate one another, such that they form a closed insulation surface.

12. The method according to claim 8 or claim 9, wherein a first electrode is chosen, in case of which the permittivity of the insulation surface formed by the first insulation and the second insulation decreases in a direction away from the working extremity.

13. The method according to claim 12, wherein the permittivity of the insulation surface formed by the first insulation and the second insulation decreases continuously at least sectionwise.

14. The method according to any one of claims 1 to 13, wherein the process zone is formed between two electrodes arranged one above the other at a distance from one another, such that the material to be fragmented and/or weakened arranged in the process zone lies on the lower electrode.

15. The method according to claim 14, wherein the first electrode is used as upper electrode.

16. The method according to any one of claims 1 to 15, wherein a closed process zone is formed.

17. The method according to claim 16, wherein the closed process zone is formed inside a closed process container.

18. The method according to claim 14, wherein an open process zone is formed.

19. The method according to claim 18, wherein a conveyor electrode is used as the lower electrode.

20. The method according to any one of claims 1 to 19, wherein the first insulation is a first insulating coating.

21. The method according to any one of claims 8 to 13, wherein the second insulation is a second insulation coating.



22. An electrode for using in the method as defined in any one of claims 1 to 21, comprising a metallic conductor having on its working extremity of the electrode, which is in contact with the processing fluid when the electrode is used as intended, partially or entirely a first insulation having a permittivity higher than 50.

23. The electrode according to claim 22, wherein the first insulation has a permittivity higher than 80.

24. The electrode according to claim 22, wherein the permittivity of the first insulation is between 60 and 100.

25. The electrode according to claim 22, wherein the permittivity of the first insulation is between 75 and 85.

26. The electrode according to any one of claims 22 to 25, wherein the metallic conductor has at the working extremity of the electrode, which is in contact with the processing fluid when the electrode is used as intended, partially a second insulation having a permittivity smaller than 50.

27. The electrode according to claim 26, wherein the second insulation has a permittivity between 2 and 10.

28. The electrode according to claim 26 or claim 27, wherein the first insulation and the second insulation are adjacent, are merged or penetrate one another, such that they form a continuous insulation surface.

29. The electrode according to claim 26 or claim 27, wherein the first insulation and the second insulation are adjacent, are

merged or penetrate one another, such that they form a closed insulation surface.

30. The electrode according to claim 28 or claim 29, wherein the permittivity of the insulation surface formed by the first insulation and the second insulation decreases in a direction away from the working extremity.

31. The electrode according to claim 30, wherein the permittivity of the insulation surface formed by the first insulation and the second insulation decreases continuously at least sectionwise.

32. The electrode according to any one of claims 22 to 31, wherein the metallic conductor of the electrode forms an annular section with rounded edge at the working extremity.

33. The electrode according to claim 32, wherein the annular section is separated from the metallic conductor by the first insulation.

34. The electrode according to claim 32 or claim 33, wherein the annular section has the first insulation at least on its surfaces showing away from the working extremity.

35. The electrode according to any one of claims 32 to 34, wherein the annular section forms the working side extremity of the electrode.

36. The electrode according to any one of claims 32 to 34, wherein a spherical segment-shaped or paraboloid-of-revolution-shaped electrode tip follows the annular section, the electrode tip forming the working extremity of the electrode.

37. The electrode according to claim 36, wherein the electrode tip is matallically blank at its free end.

38. The electrode according to any one of claims 26 to 31, wherein the electrode has an insulating body made of a material with a permittivity smaller than 20, out of which the metallic conductor protrudes at the working extremity.

39. The electrode according to claim 38, wherein the insulating body is interspersed with one or more annular elements, which are concentric to the metallic conductor penetrating the insulating body and made of a material with a higher permittivity than the material of the isolator.

40. The electrode according to claim 38 or claim 39, wherein the metallic conductor has the first or the second insulation in the section where it body protrudes out of the insulating body.

41. The electrode according to any one of claims 22 to 40, wherein the first insulation is a first insulation coating.

42. The electrode according to any one of claims 26 to 31 or 38 to 40, wherein the second insulation is a second insulation coating.

43. A device for fragmenting and/or weakening material by means of high-voltage pulses with two electrodes of which at least one is formed as an electrode as defined in any one of claims 22 to 42, wherein a process zone is formed between the two electrodes, in which the material to be fragmented and/or weakened and a processing fluid can be arranged such that the entire process zone is flooded with processing fluid, and wherein high-voltage



pulses are applied to the electrodes such that high-voltage breakdowns occur between the two electrodes and/or such that predischARGE channels are formed without breakdowns.

44. The device according to claim 43, wherein the device is for fragmenting and/or weakening rock material or ore.

45. The device according to claim 43 or claim 44, for carrying out the method as defined in any one of claims 1 to 21.

46. The device according to any one of claims 43 to 45, wherein each of the two electrodes is formed as the electrode as defined in any one of claims 22 to 42.

47. The device according to any one of claims 43 to 46, wherein the two electrodes are arranged one above the other in such a way that the material to be fragmented and/or weakened lies on the lower electrode when the process zone is flooded.

48. The device according to claim 47, wherein at least the upper electrode is formed as the electrode as defined in any one of claims 22 to 42.

49. The device according to any one of claims 43 to 48, wherein the process zone is formed in a closed container.

50. The device according to any one of claims 43 to 48, wherein the process zone is formed as opened process zone.

51. The device according to claim 50, wherein both electrodes are arranged above one another and the lower electrode is formed as conveyor electrode.

52. A use of the electrode as defined in any one of claims 22 to 42 or of the device as defined in any one of claims 43 to 51 for fragmenting and/or weakening material by means of high-voltage pulses.

53. The use according to claim 52 for fragmenting and/or weakening rock material or ore.

54. The use according to claim 52 or claim 53, for carrying out the method as defined in any one of claims 1 to 21.

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Fig.1

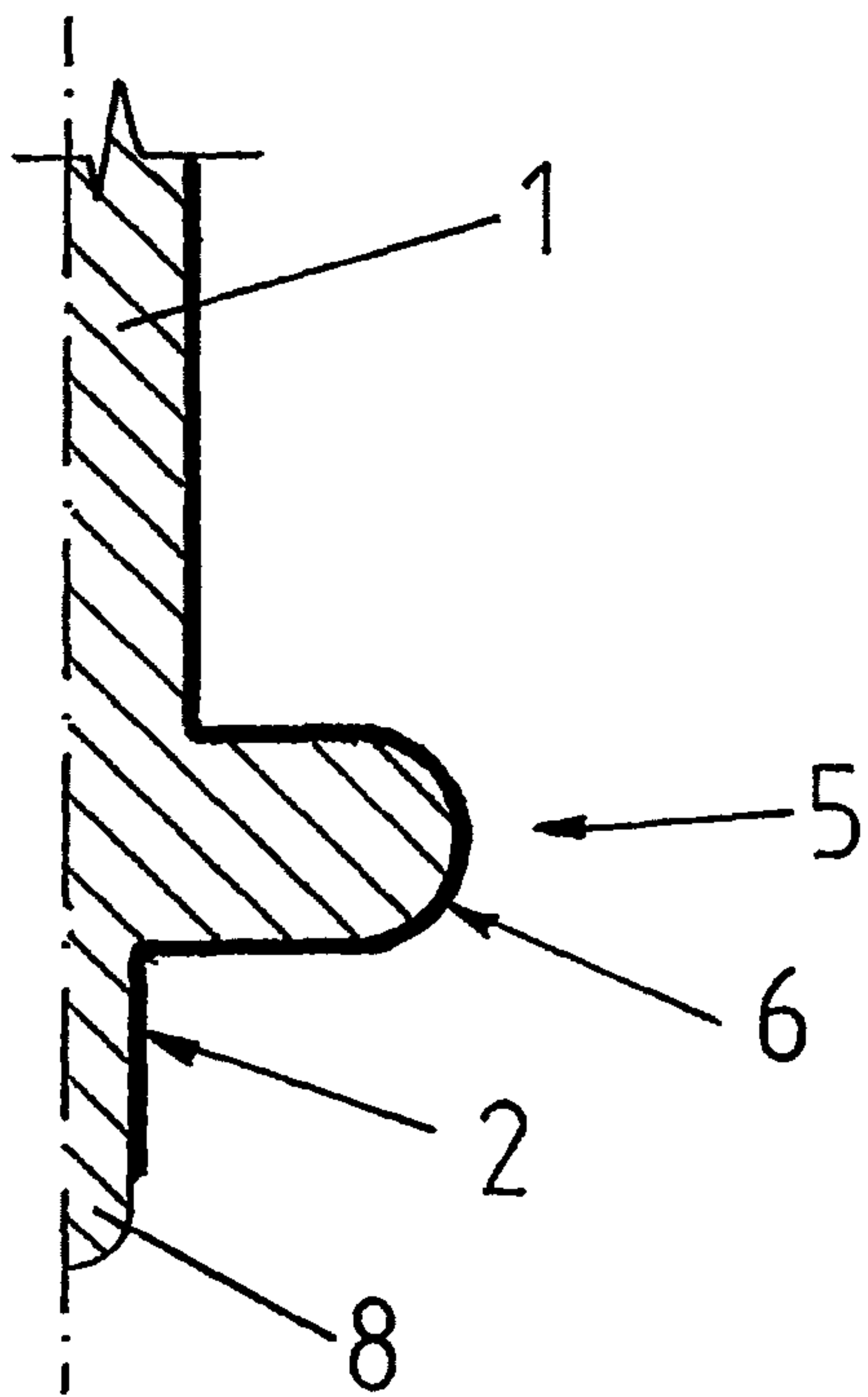
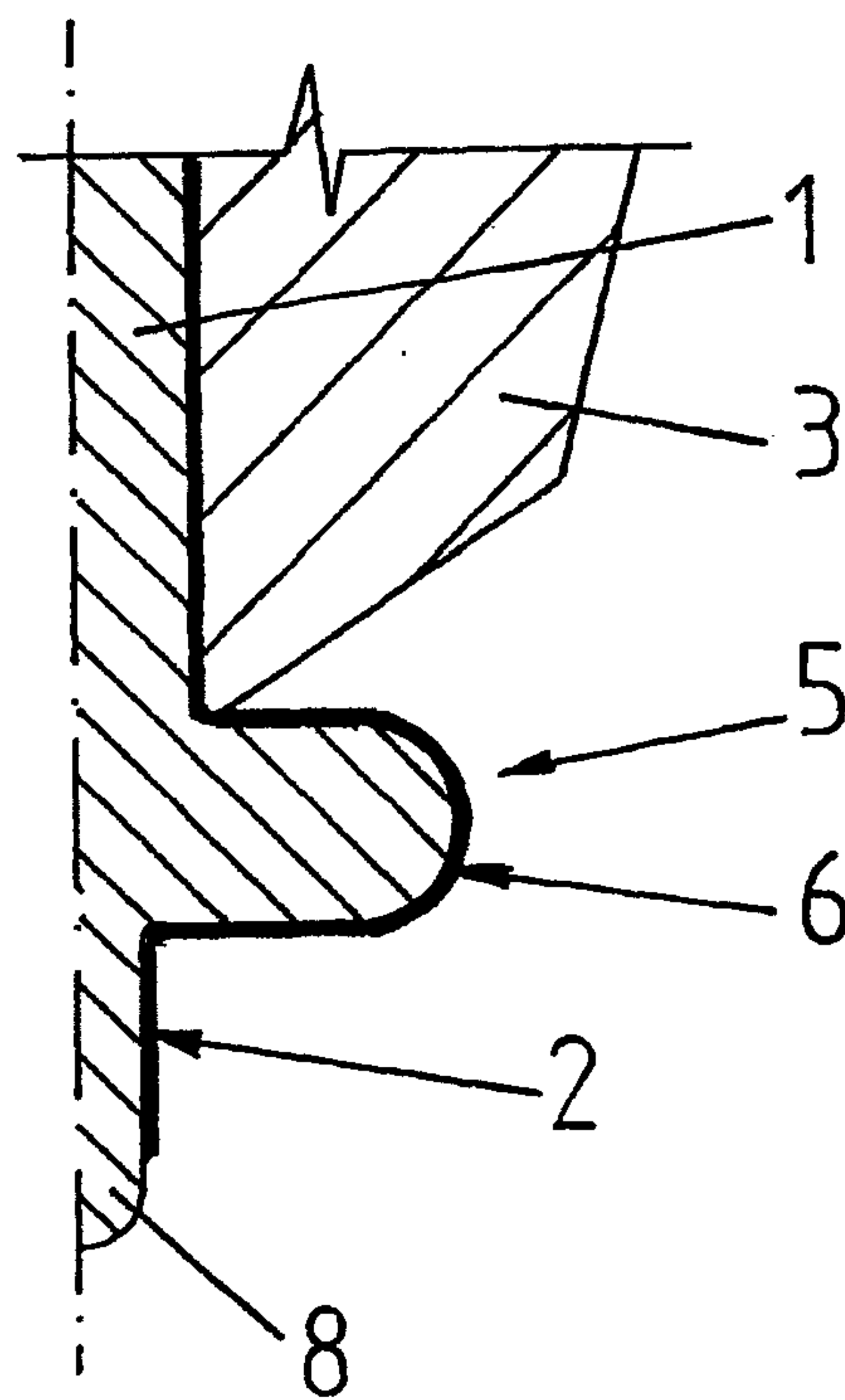


Fig. 2





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Fig.3

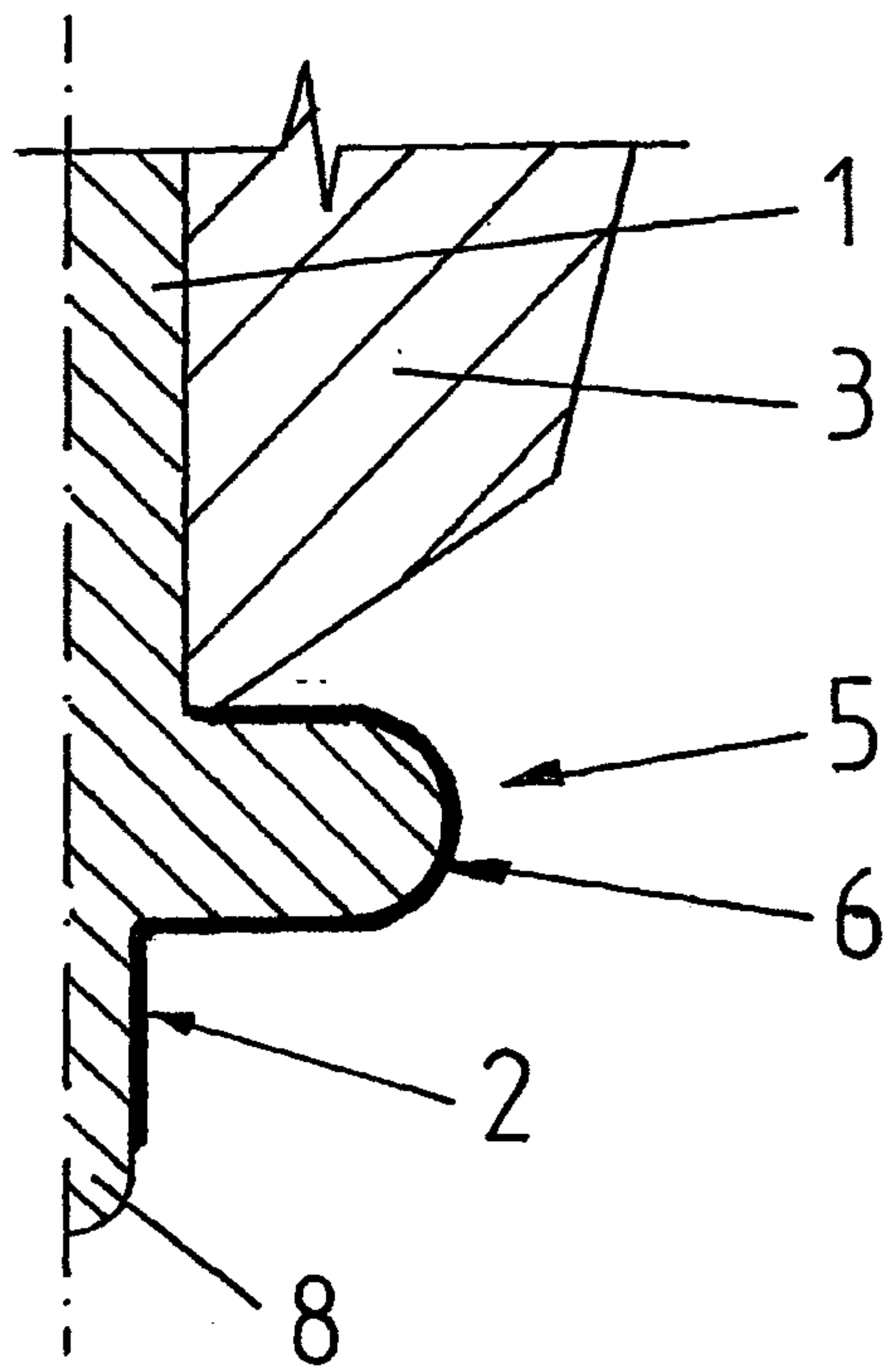
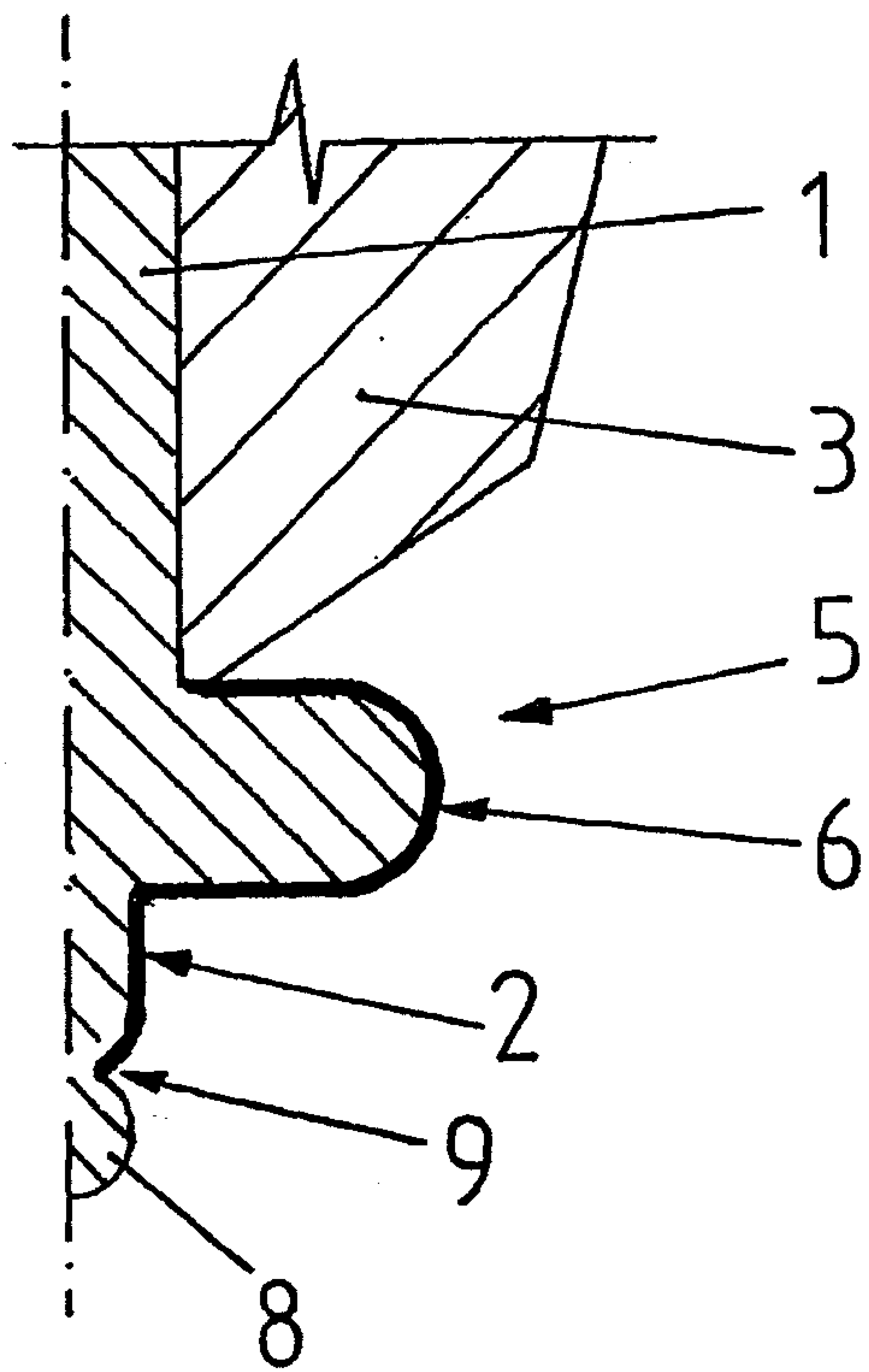


Fig.4



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Fig.5

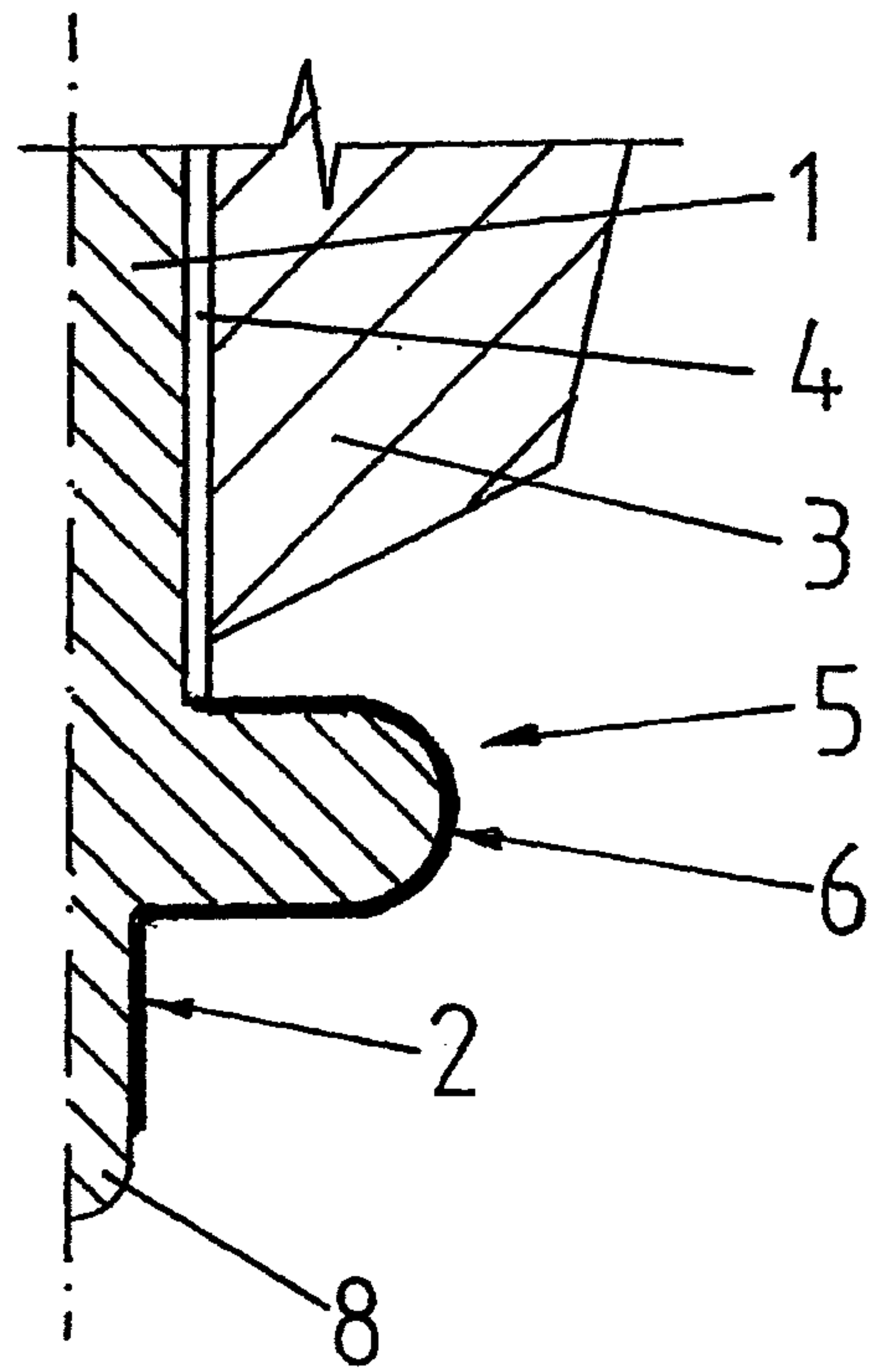


Fig.6

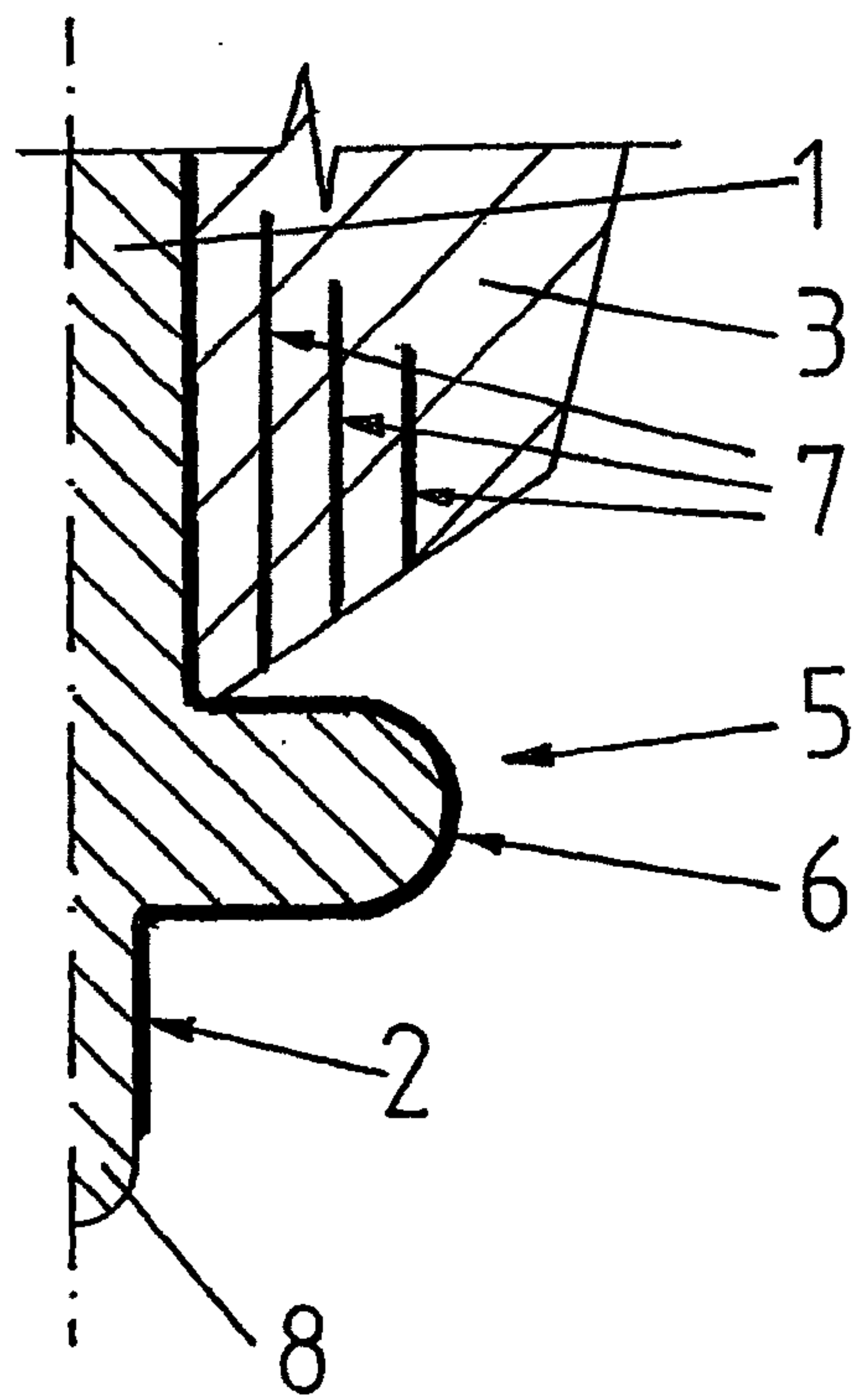


Fig.7

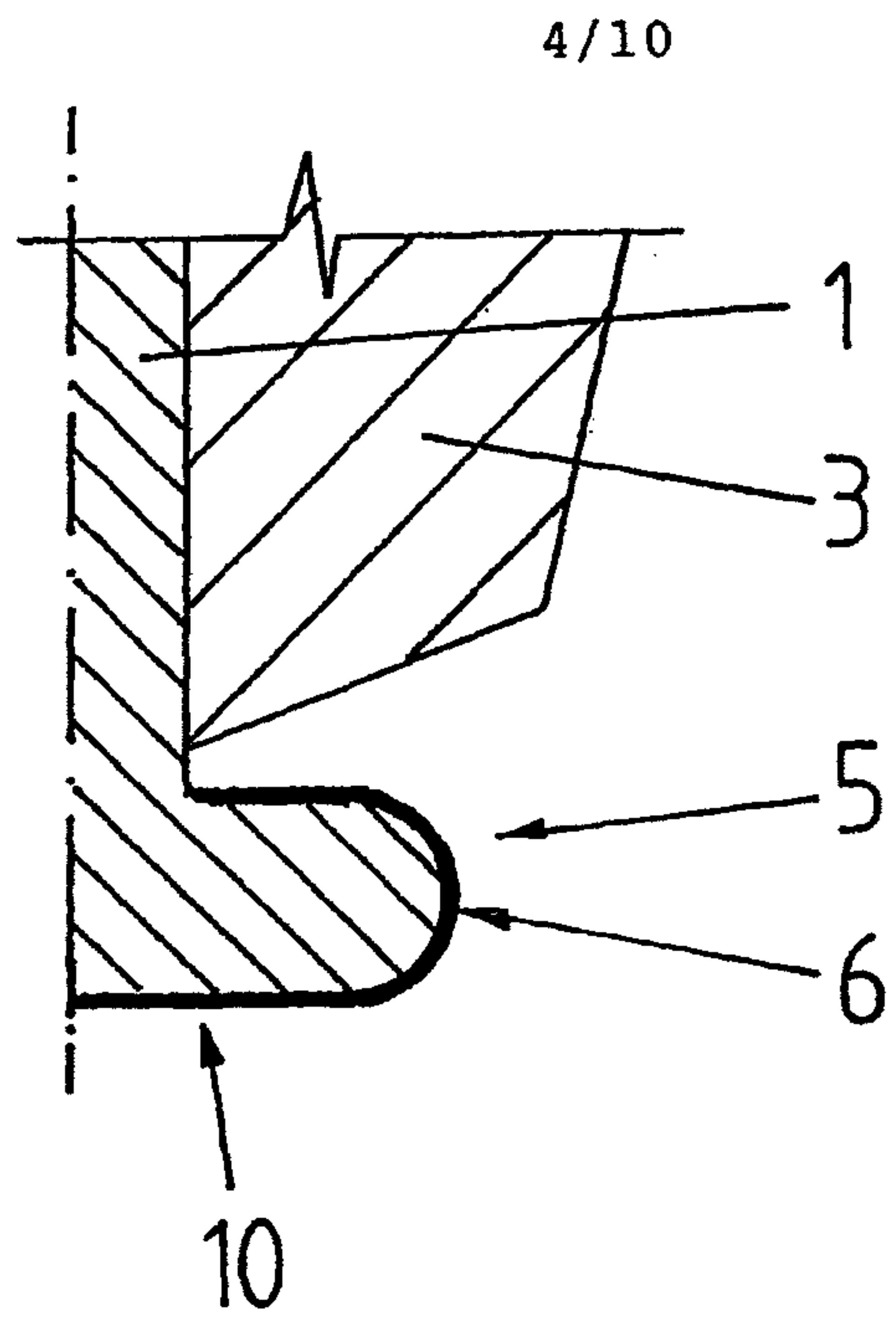
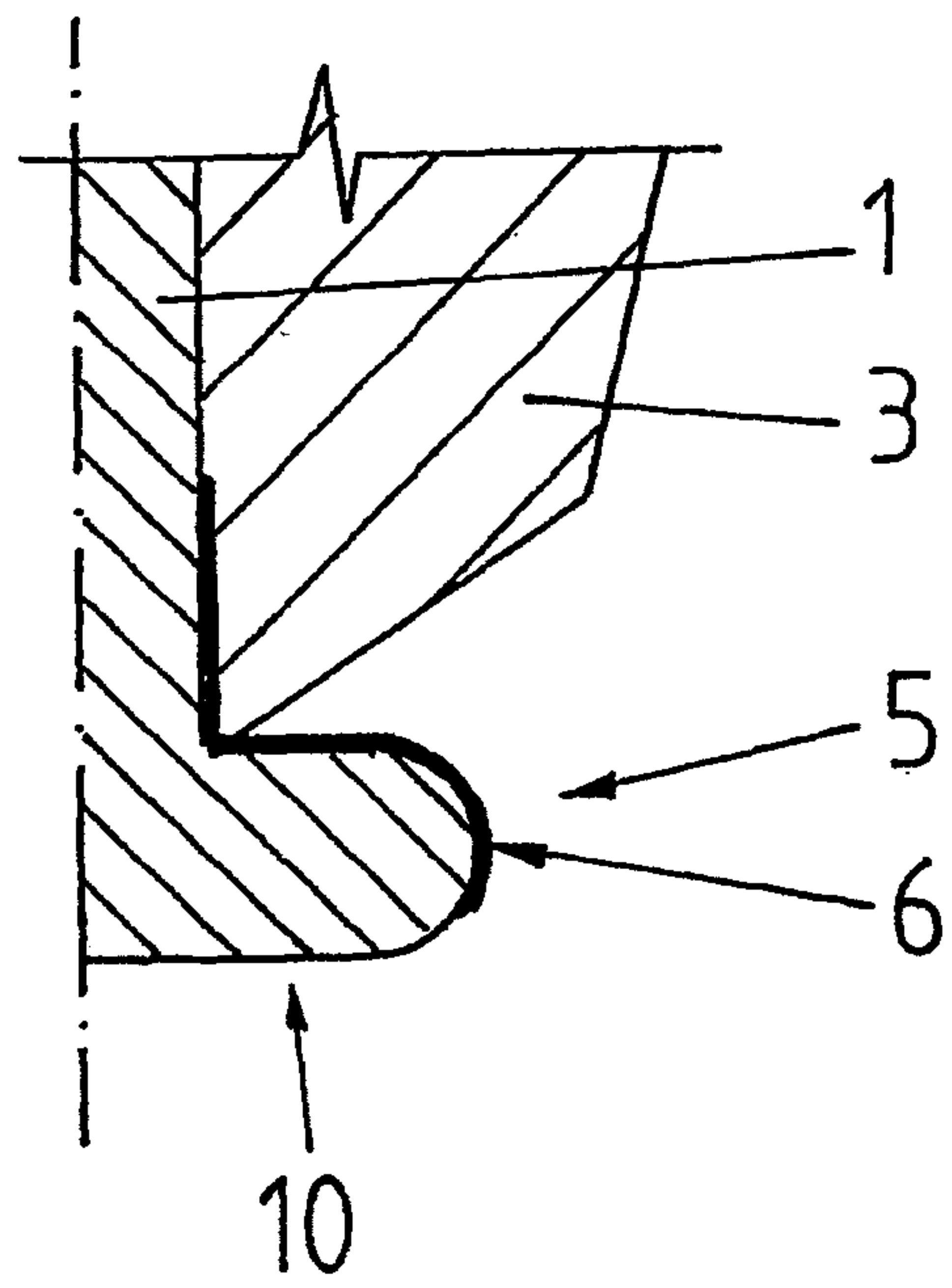


Fig.8





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Fig.9

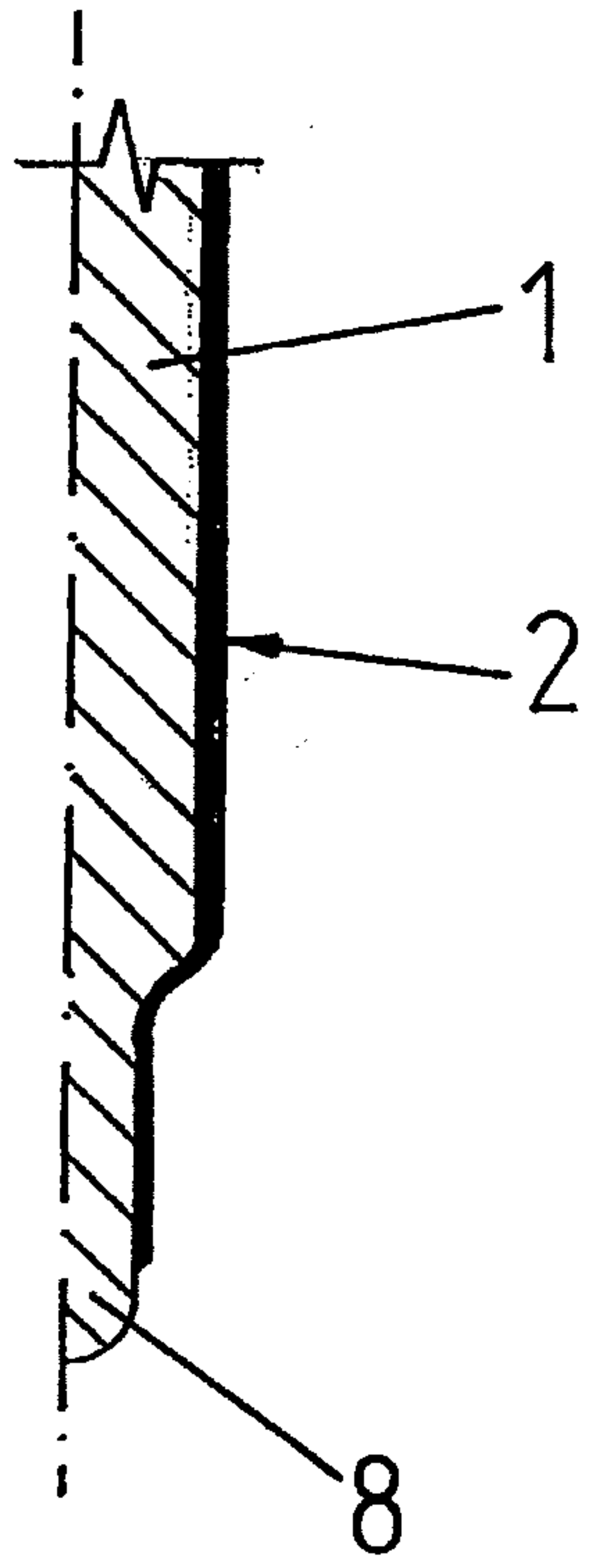
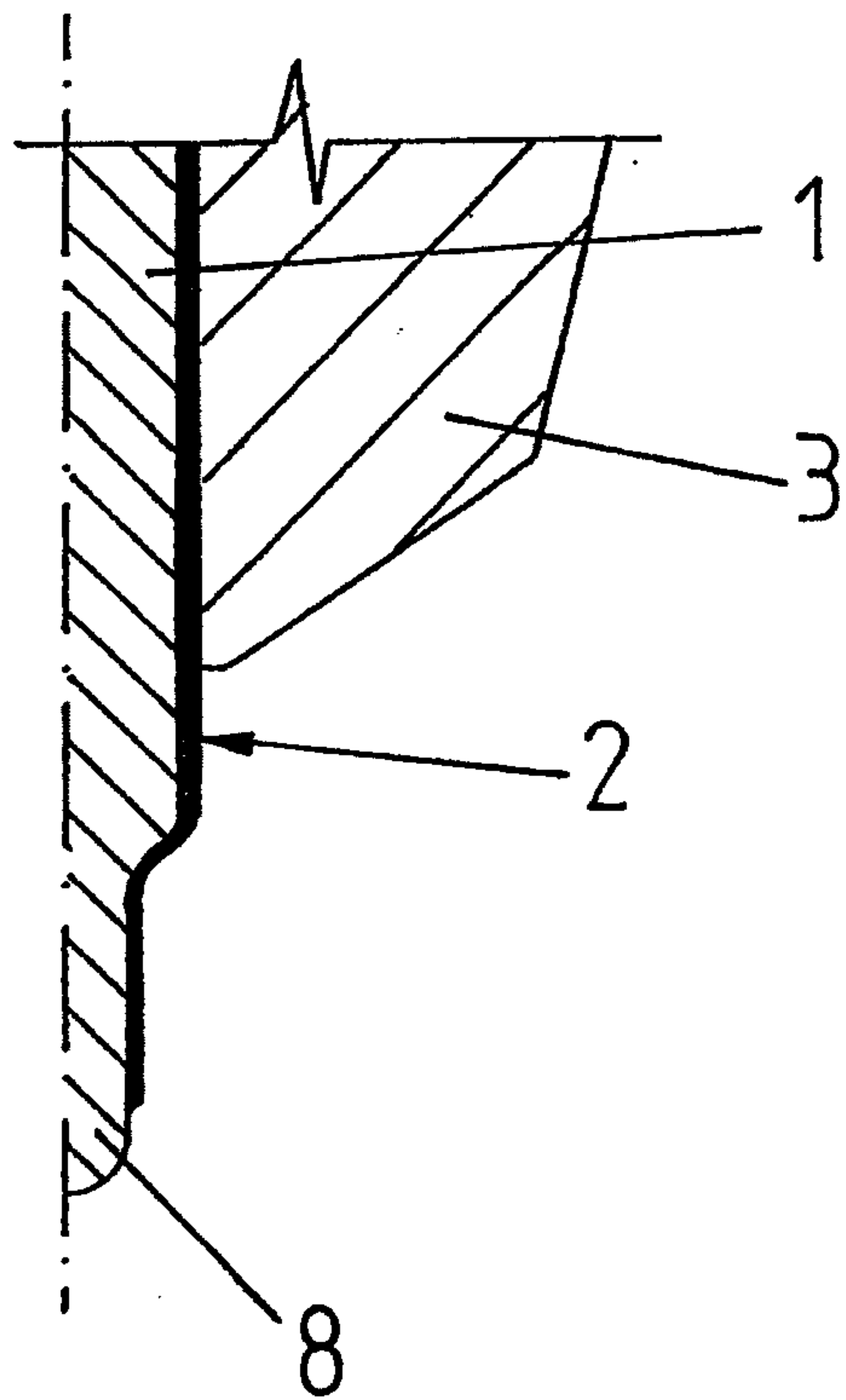


Fig.10



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Fig.11

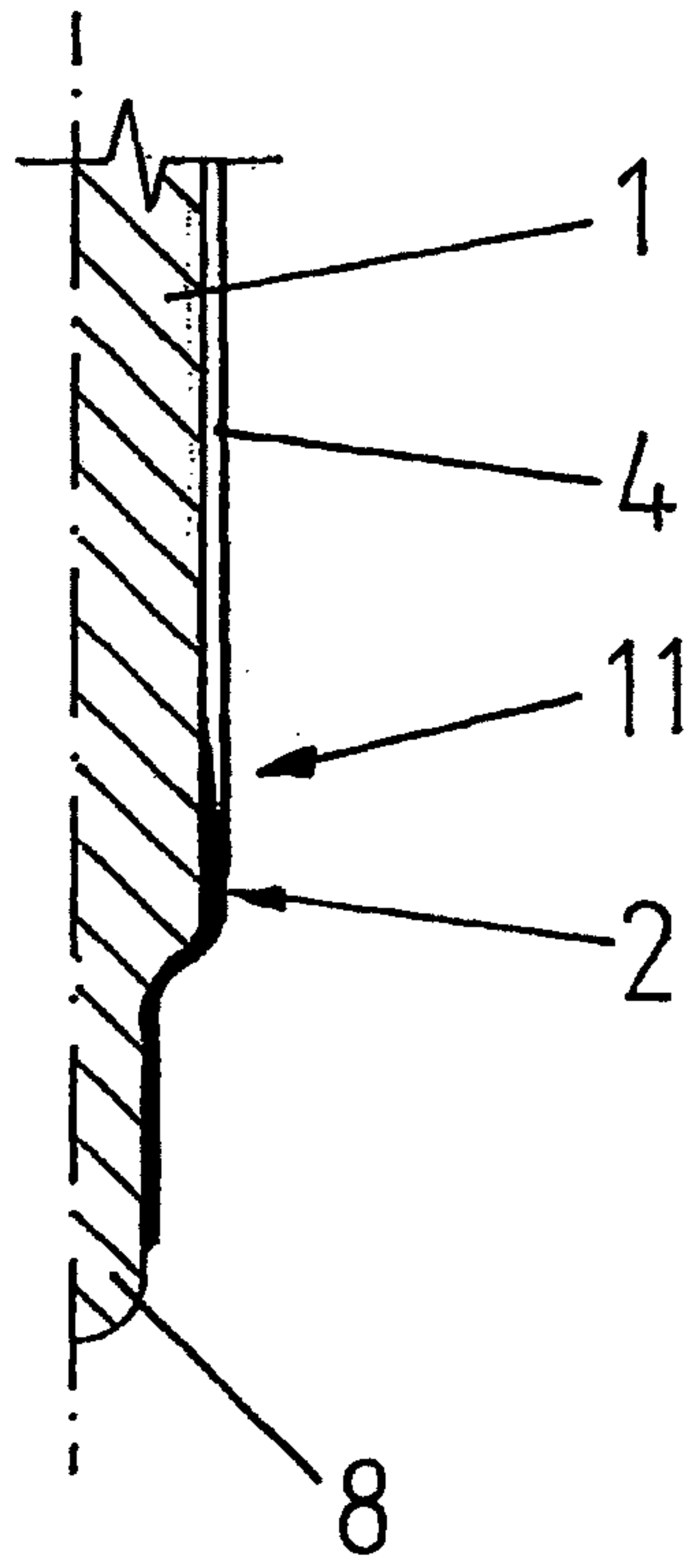
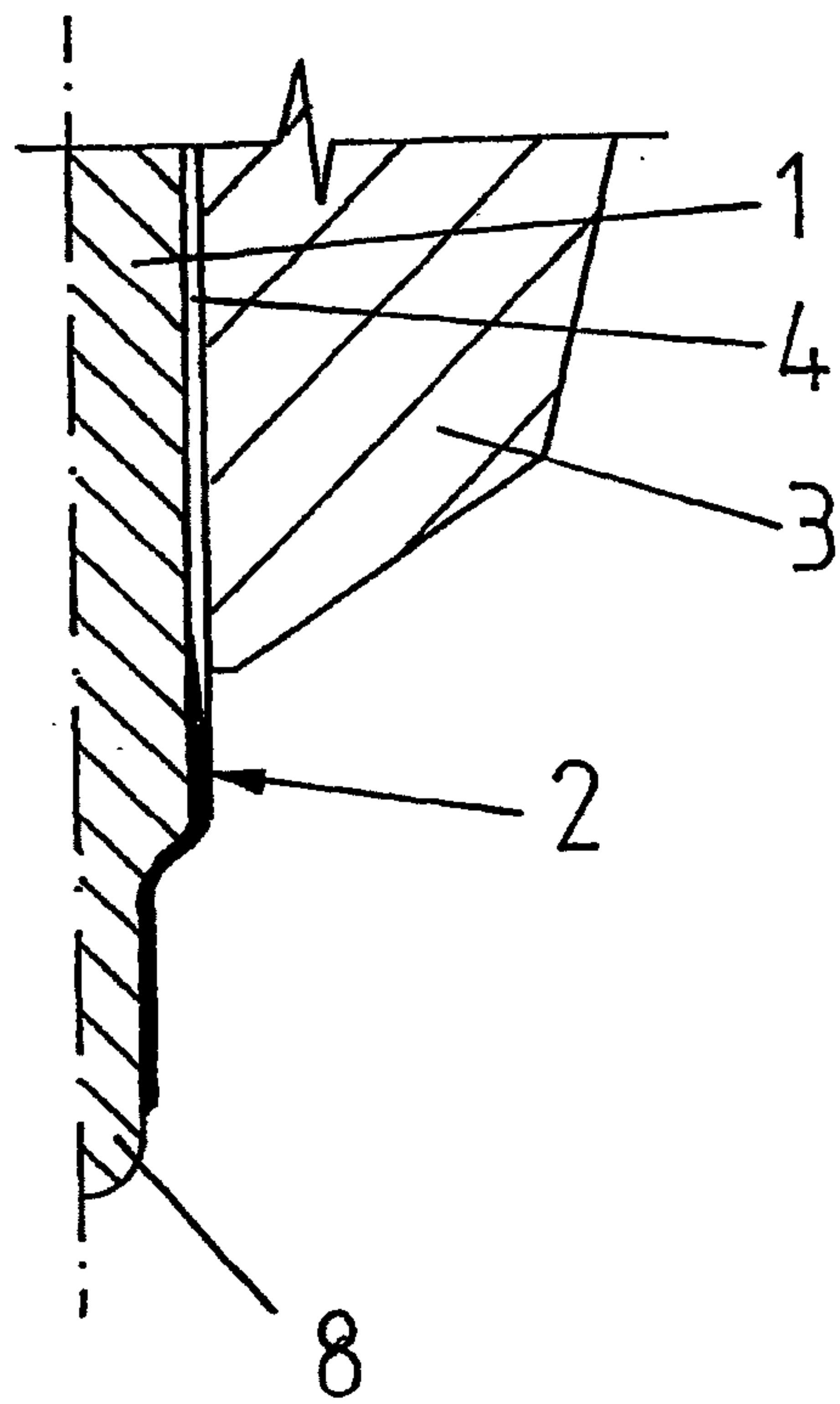


Fig.12



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Fig.13

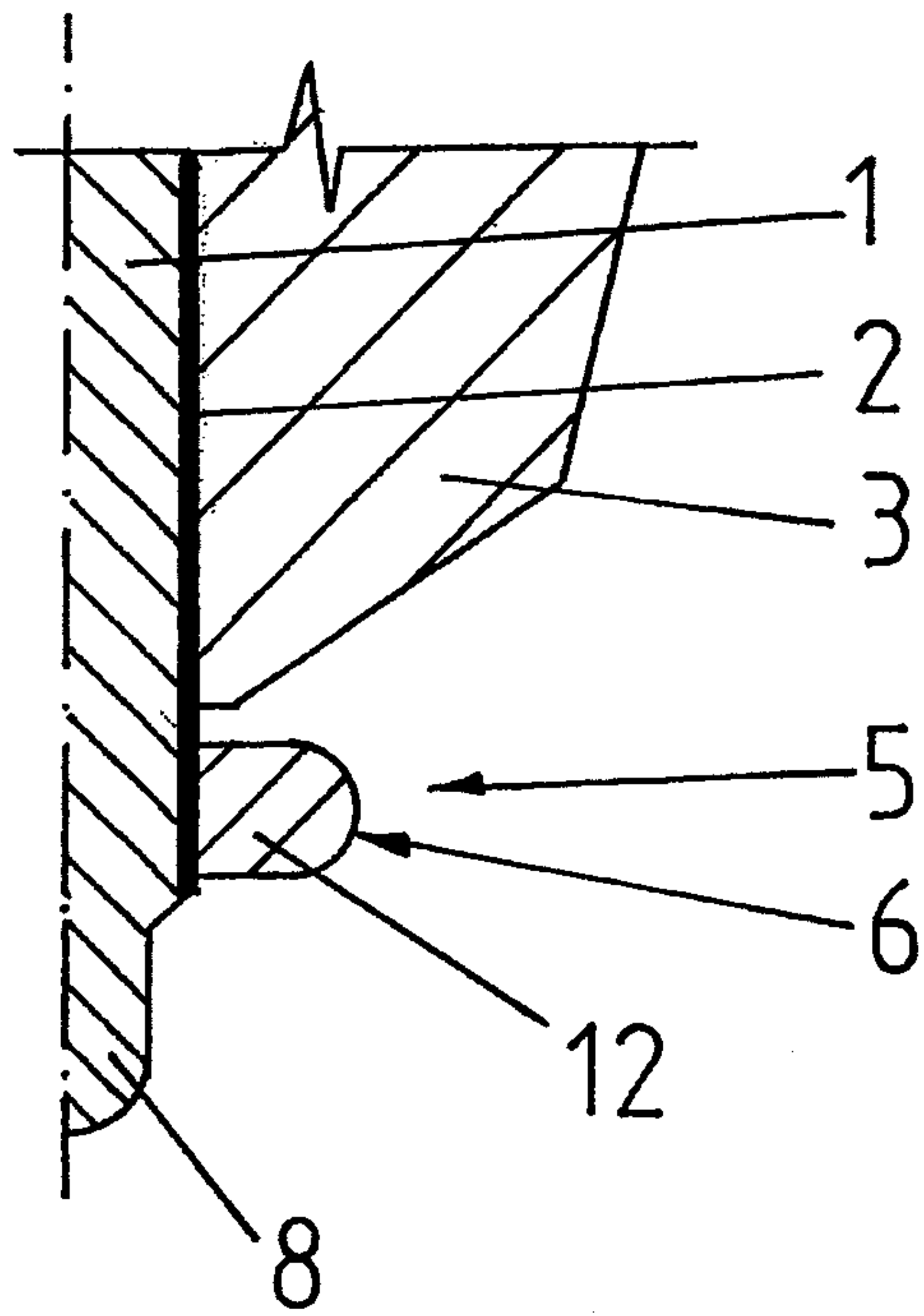
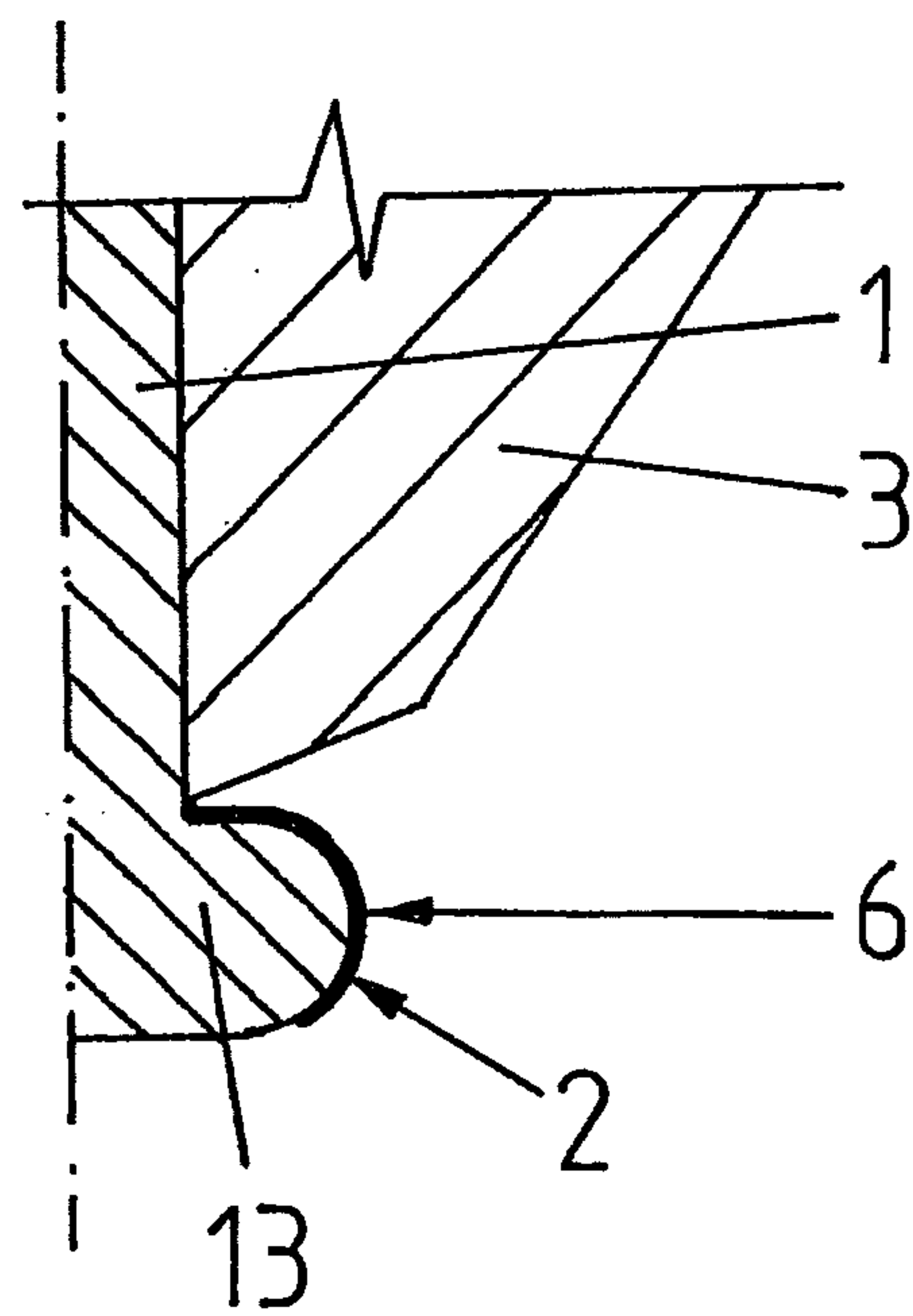


Fig.14





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Fig.15

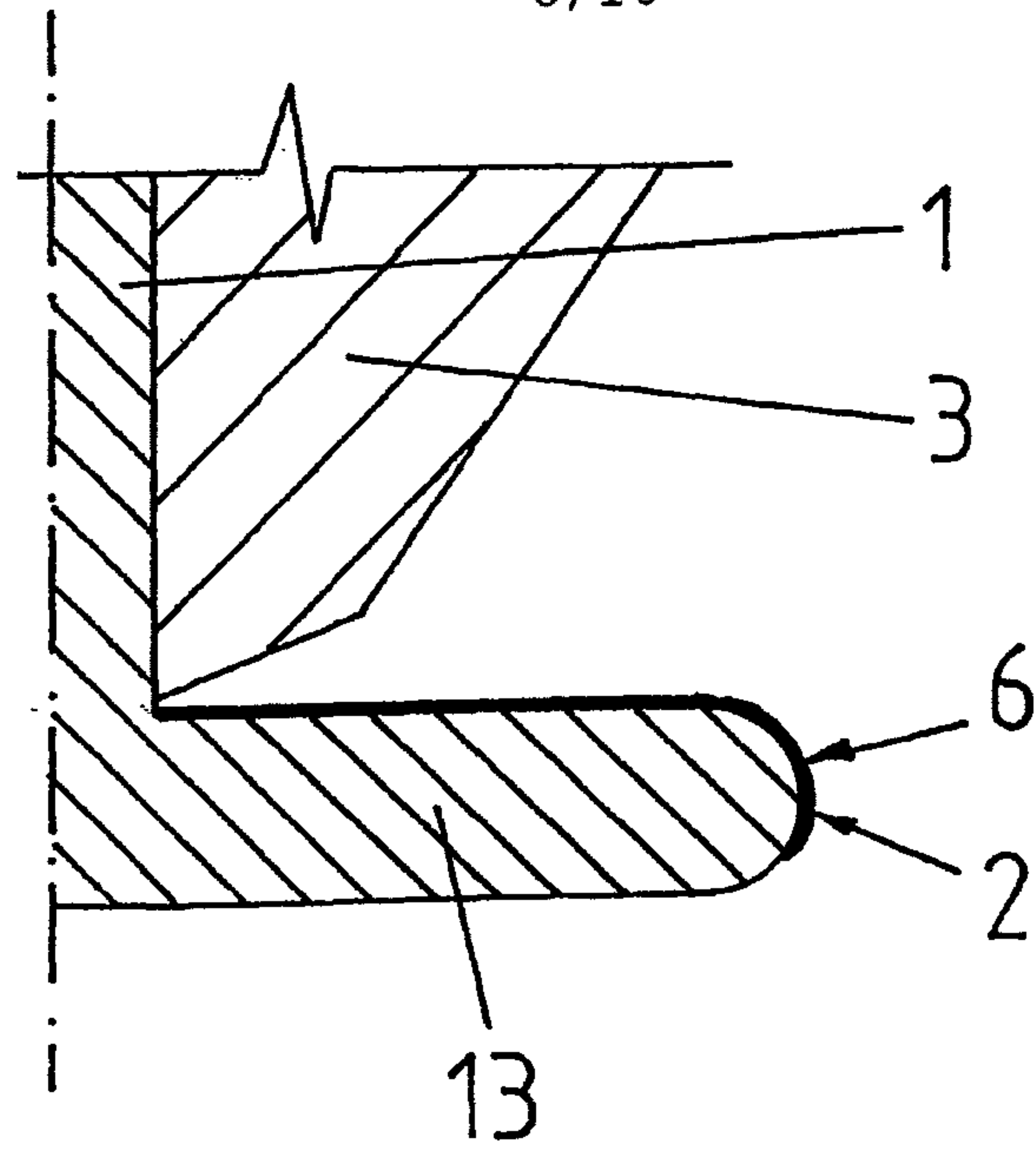
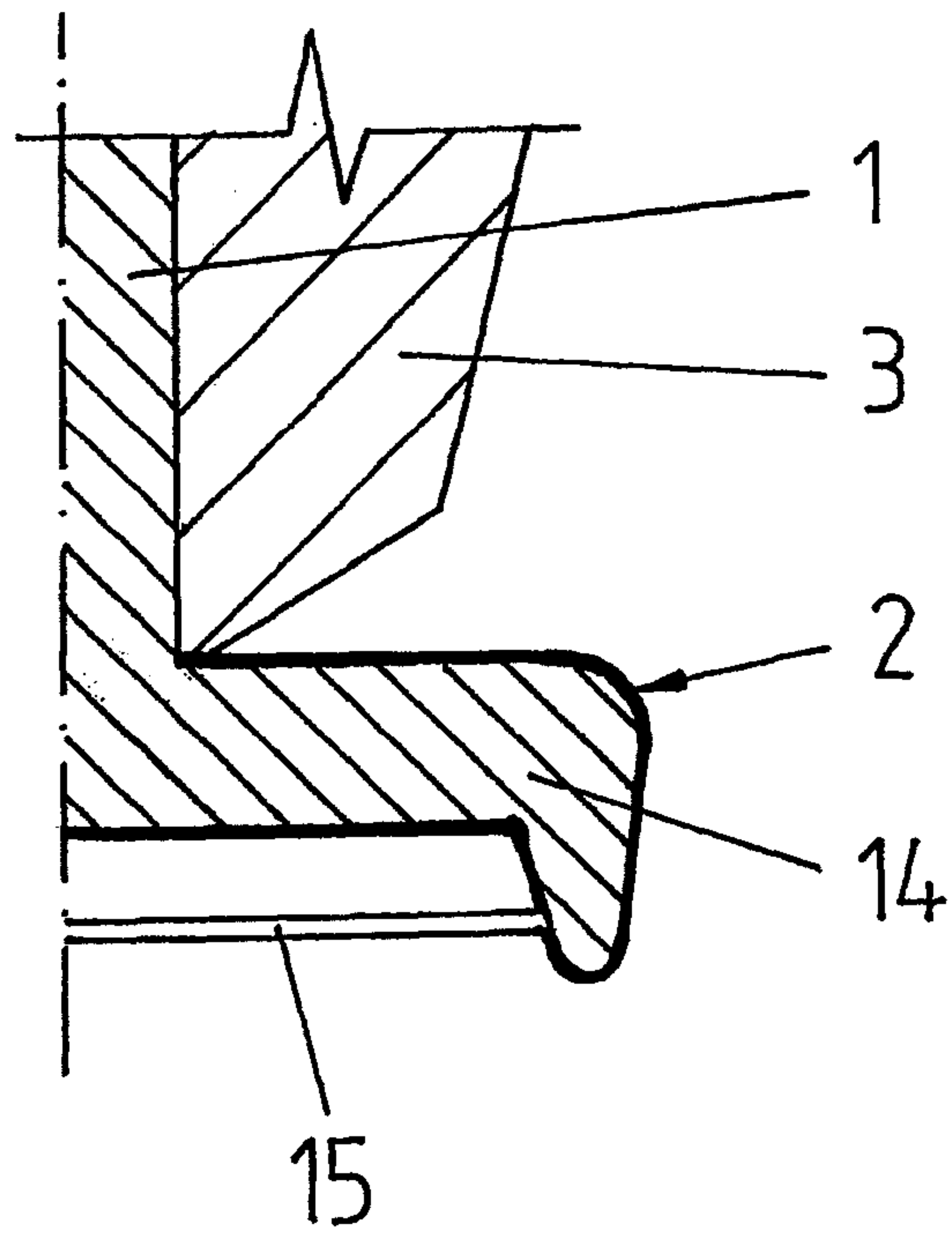
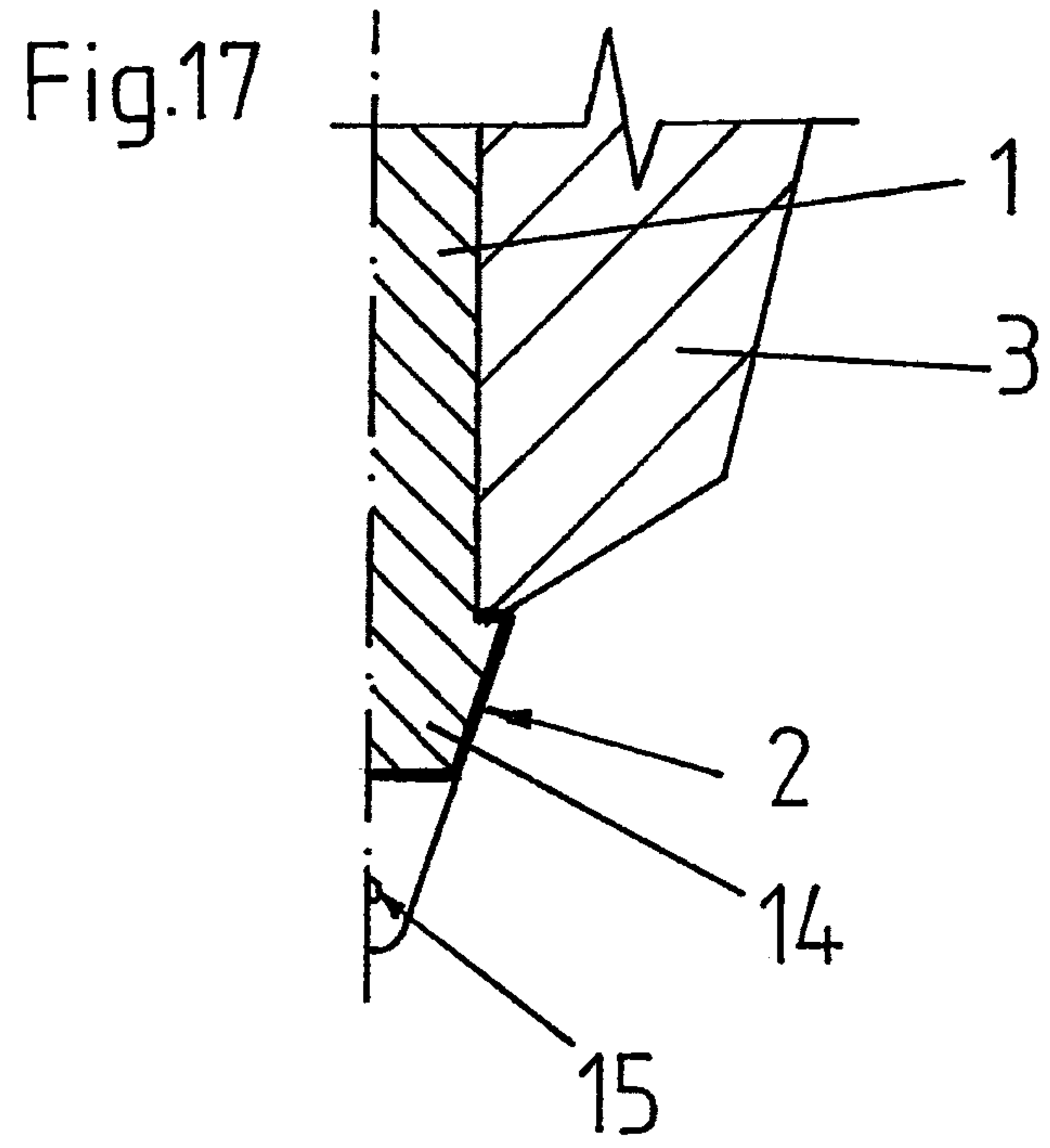


Fig.16





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Fig.18

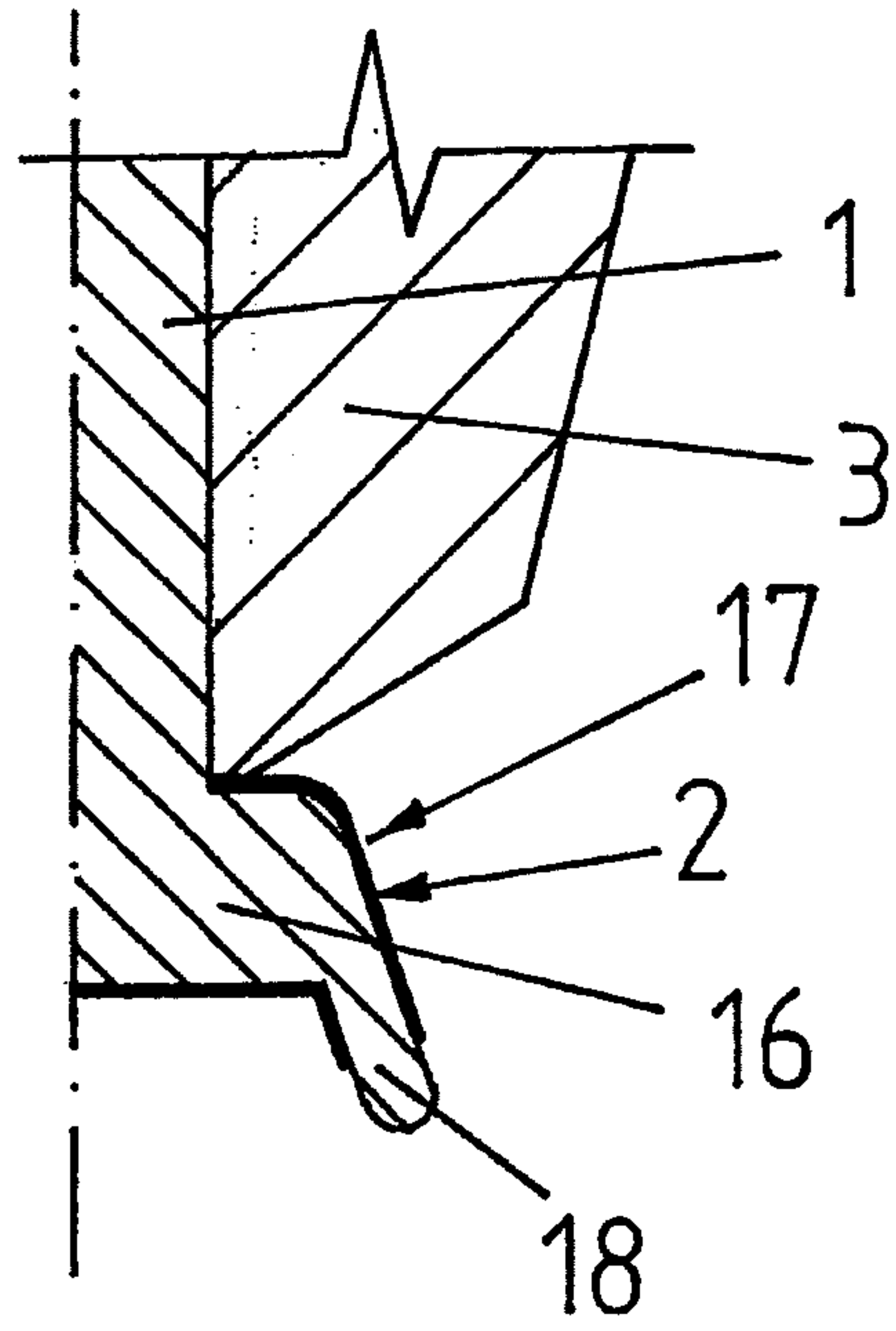


Fig.19

