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(54) Benævnelse: **SVEJSEFREMGANGSMÅDE OG INDRETNING TIL SAMMENFØJNING AF OVERLAPPENDE PLADER**

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WELDING METHOD AND DEVICE FOR JOINING OVERLAPPING SHEETS

The invention relates to a welding method for joining overlapping sheets by means of a wire-shaped or strip-shaped metallic welding wire that melts in the arc of a metal inert-gas-shielded welding device, and a metal inert-gas-shielded welding device for carrying out the method.

A wide variety of methods for joining overlapping or superposed sheets are known from the prior art, among others the spot-welding methods. These include not only the well-known resistance spot-welding but also the spot-welding methods by means of an arc, such as the WIG, the MAG spot-welding, or the plug-welding. They are particularly suitable when the components to be welded are only accessible from one side. With the WIG or MAG spot-welding, the sheets are fused at a specific position and a weld nugget is formed that material-fittingly joins the sheets in the overlapping region.

DE 198 82 096 B4 discloses a method for spot-welding several workpieces lying flat on top of one another, according to which, firstly, a hole is introduced into a workpiece by means of a plasma arc. Then, the workpieces are fused and welded with the plasma arc with the simultaneous introduction of a filling material. The disadvantage of this method is that the filling material is fed separately into the region of the plasma arc.

A similar method for joining overlapping components according to the preamble of claim 1 is described in DE 10 2010 044 886 A1. Accordingly, a hole in the upper component is filled with a filler metal, whereby a material-fitting joint with the lower component is created.

According to the plasma arc spot-welding described in DE 10 2008 033 415 A1 to produce a multi-sheet metal joint, ionized plasma is blown through the sheet-shaped joining partners at the welding site in order to initially melt them and then fuse them together. The problem with this method is that when the molten weld metal is blown through, inclusions of gases can arise in the same. Hence, further method steps are required for degassing. Welding material is fed into the joining site from the side by means of a welding wire.

Also known from EP 0 857 533 A1 is a method for metal inert-gas-shielded welding according to which the wire electrode can be guided through a contact tube, wherein particular advantages of the method are achievable by maintaining a spacing between the contact tube and the component. Spacers for welding torches are also disclosed in US 2009 /0230107 A1.

Welded joints of sheets made of dissimilar materials, especially those with quite different material properties, such as different melting temperatures, place special demands on the welding methods used therefore to achieve the required material quality in the joining zone. By mixing of the joining materials involved in the welding method alloys and/or intermetallic compounds with undesirable properties, e.g., too low strength or too high brittleness, can be formed in the weld metal.

Welding steel with aluminium materials is a well-known example for such a behaviour. During mutual fusing and subsequent solidifying, a brittle joining layer is formed, which can only be subjected to slight loads when exposed to external forces. Hence, the welding process must be strictly controlled for methods for joining steel and aluminium sheets. Thus, e.g., one joining partner can be completely fused and the other joining partner can only be partly fused. An example of this is described in DE 103 04 954 A1.

The disadvantage of the known welding methods is that they exclusively produce a material-fitting joint between the joining partners. As a result, these joining methods are problematic for combinations of materials that are incompatible in terms of alloying technology, i.e., those, where brittle phases develop during welding or where the miscibility of the materials is limited.

The object of the invention is to overcome the disadvantages mentioned and to provide a method which enables a material-fitting and form-fitting spot-welded joint of overlapping sheet materials. The welding method is also intended to avoid the formation of undesirable brittle phases or alloys when joining materials of different types.

According to the invention, the above-mentioned object is achieved with a method according to claim 1; appropriate embodiments of the invention can be found in the dependent claims.

According to the invention, overlapping sheets are welded by means of a meltable, wire-shaped or strip-shaped starting material, hereinafter generally referred to as welding wire, wherein an electric arc being used as an energy source for fusing the sheets and the welding wire. During the welding process the sheets to be joined are penetrated by the welding wire in the region of a specified joint site.

To carry out the method according to the invention, a metal inert-gas-shielded welding device is used, as is customary for the generally known GMAW (Gas Metal Arc Welding) methods of metal inert gas welding (MIG) or metal active gas welding (MAG). This device has a welding torch and a wire feed facility, the latter being able to generate a wire feed of the welding wire, which for this purpose is guided movably in its longitudinal direction inside the welding torch.

The overlapping sheets comprise at least an upper sheet and a lower sheet, wherein thin sheets are preferably used for the method according to the invention.

The welding torch is positioned at the desired joining site with specified spacing above the upper sheet from its surface, wherein the welding wire is aligned at an angle of 90 ± 30° to the sheet plane of the upper sheet.

The welding wire is then moved in the direction of the upper sheet by means of the wire feed facility with a variably adjustable wire feed speed and the arc is started between the upper sheet and the welding wire. The starting can take place by means of a well-known starting process, e.g., the lift-arc method.

In the region of the arc, the upper sheet and the welding wire are now fused, whereby a trough-shaped puddle of molten weld metal is formed.

In the following, the term weld metal is understood to mean the fused and re-solidified material in the welded joint. This can vary in its composition depending on the proportions of melted material from the various sheets and the welding wire. Initially, however, the molten weld metal is only formed from the materials of the melting welding wire and the upper sheet.

Due to the continuous wire feed, the welding wire presses the molten weld metal onto the lower sheet - directly through mechanical contact or indirectly through the arc plasma running in front of the welding wire tip. Thereby, the lower sheet is melted through.

This pressing of the molten weld metal onto the lower sheet by means of the welding wire is achieved by controlling the wire feed speed, wherein it is also provided to vary the wire feed speed. The average wire feed speed is in the range from 10 to 40 $m \cdot min^{-1}$. In comparison, wire feed speeds in the range from 1 to 25 $m \cdot min^{-1}$ are generally used in metal inert-gas-shielded welding.

When the lower sheet melts through, a breakthrough with a smaller lateral extent than that of the trough-shaped weld metal puddle is produced in it. At the edges of this breakthrough, the lower sheet is only partially melted, i.e., only a narrow zone with metallurgical interaction is formed between the weld metal and the lower sheet.

The molten weld metal, which consists essentially of the material of the welding wire and the upper sheet, is pressed through the narrow site of the breakthrough due to the continuous movement of the welding wire.

The processes of pressing the molten weld metal onto the lower sheet by means of the welding wire, melting through the lower sheet and pressing through the weld metal are collectively referred to as penetration.

After penetration, the joining site is filled-up with molten weld metal, which mainly consists of the welding wire that is continuously melting in the arc.

After a determined welding time, which depends on the set process parameters or process events, the arc and the wire feed facility are switched-off according to a generally known end process. The weld metal solidifies in the shape of drops in the region of the breakthrough on the surface of the lower sheet facing away from the welding torch. In the following, this region of the solidified weld metal is referred to as the closing head; the solidified region of the weld metal inside the upper sheet resulting from the trough-shaped puddle is referred to as the performed head and the solidified weld metal in the region of the breakthrough in the lower sheet is referred to as the shank.

Because of the wire feed speed used, welding times for welding thin sheets are typically of the order from 0.1 to 1.0 seconds. In comparison, in the generally known MAG spot-welding methods the welding times are about 1 to 3 seconds.

By controlling the wire feed speed and welding time and the amount of weld metal resulting therefrom that is being pushed through the breakthrough in the lower sheet, the closing head - like the performed head - has a substantially larger lateral extent than the shank.

Thus, in addition to the material-fit, the method described also provides the form-fit of the spot welded joint according to the object of the invention.

The invention links specific characteristics of fusion welding with those of riveting. The manifold advantages of the method according to the invention, which are described in the following only in outline, arise from the synergy effects of the combination of the characteristics of the joining methods.

The similarity of the spot-welded joint produced by the method according to the invention to a riveted joint is easy to see: in terms of their structure and functionality, the closing and performed heads correspond to the closing and performed heads of the riveted joint; the shank corresponds to the rivet shank.

One of the advantages of the method according to the invention is that the component weight and the dimensions of the joined components are largely unchanged after the welding. In terms of construction, the installation space can consequently be fully utilized when using the sheets that are spot-welded in this way in contrast to, e.g., screw connections that require a considerable amount of space and significantly increase the weight of the joined assembly.

Customary, widespread, and inexpensive welding devices can be utilised to carry out the welding method. The construction of the device and the implementation of the method can be realised easily and at short notice by professionally trained personnel. The invention thus provides an extremely cost-effective and timesaving spot-welding method.

In contrast to classic riveting or resistance spot-welding, the method according to the invention only requires one-sided access to one of the surfaces of the sheet components to be joined. Thus, the method is exceptionally suitable for, e.g., attaching sheet cladding.

Another advantage is - although it is a fusion welding method - the low heat input into the sheets to be joined. As a result, there are only minimal, locally limited distortions in the components. Elaborate straightening work can be dispensed with.

It should be particularly emphasized that sheet materials of different types can be welded to one another by means of the method according to the invention. This is made possible by suppressing extensive metallurgical interactions as a result of the short welding times that are typical of the method. The rapid passage of the molten weld metal through the lower sheet prevents pronounced alloy zones or intermetallic compounds from forming.

Another advantage results from the combination of the form-fitting and material-fitting in the joint, caused by the characteristic shape of the solidified weld metal - comparable to a rivet. The redundant acting physical joining principles lead to a fail-safe spot welded joint ("fail-safe behaviour"). Thus, e.g., defects in the weld between the weld metal and sheet materials can be tolerated to a certain extent without causing the joint to fail. Hence, the spot welded joint according to the invention is suitable for safety-relevant welded joints.

In addition, after solidification, the weld metal shrinks as it cools down further. As a result, tensile stresses are generated in the welding direction, i.e., axially, which in turn apply compressive stresses to the superposed sheets. Therefore, in addition to a form-fit and material-fit, a force-fitting component contributes to the secure joint of the sheets.

Specific embodiments of the invention are discussed below.

In one embodiment, one or more intermediate sheets can be inserted between the upper and lower sheets. The welding process is controlled depending on the materials of the individual sheets and the intended structure of the spot weld joint such that the performed head or the shank enclose the region of a specific intermediate sheet. With this embodiment of the method, not only two but several sheet-metal components can be joined.

It can be provided that the joining site is supplied with a shielding gas by means of the metal inert-gas-shielded welding device. The use of shielding gas veils to shield the molten weld metal from the ambient atmosphere prevents gas absorption in the weld metal as well as its undesired oxidation. On the one hand, inert gases such as nitrogen or the noble gases argon and helium, or on the other hand, active gases such as carbon dioxide or gas mixtures containing carbon dioxide, are suitable. With the latter gases the welding process can be active, e.g., with regard to penetration, droplet size or spatter losses, in addition to the shielding against the ambient atmosphere. The selection of the shielding gas depends primarily on the materials to be welded. The noble gas argon is widely used as a shielding gas and can be used universally when welding a wide variety of materials.

In a further embodiment of the invention, a metal, or a metal alloy with a high melting point, e.g., an iron, nickel, titanium or molybdenum-based metal alloy, and a metal or a metal alloy with a low melting point, e.g., an aluminium, magnesium, copper-zinc or copper-tin-based metal alloy is used. The high thermal energy, which is stored in the molten weld metal after fusing the upper sheet, enables the low-melting material of the lower sheet to melt through particularly quickly when the welding wire is fed in. As a result, the method according to the invention for joining overlapping sheets with quite different melting temperatures of the materials is extremely effective.

Suitable in this embodiment of the invention are, e.g., the material combinations of steels with aluminium alloys, bronze, or brass as well as nickel or titanium alloys with the aforementioned aluminium and copper alloys.

Furthermore, coated sheets can also be joined by means of the method. In addition to the intended protection against corrosion or wear, the coatings can also improve the quality of the spot-welded joint in that, e.g., the coating materials in the vicinity of the joining site participate in metallurgical interactions and contribute to the material-fitting joint. Likewise, the joined sheets according to the invention, can be welded, e.g., in a sandwich-like construction made of sheets with plastic inserts.

According to the invention, the method can also be used to join materials of different types with similar melting temperatures. Hence, it is possible, e.g., to weld an upper sheet made of a steel material or a nickel alloy with a lower sheet made of a titanium alloy. The poor conductivity of the titanium alloy means that the breakthrough in the lower sheet remains spatially narrow, since the thermal energy is concentrated at the central contact site of the molten weld metal with the lower sheet when the welding wire is fed in.

In an advantageous manner, the metal inert-gas-shielded welding device for carrying out the method according to the invention includes a spacer which ensures that the welding torch is stopped at a specified spacing from the surface of the upper sheet facing the welding torch. Thus, fluctuations in position of the welding wire due to movements of the welding torch, e.g., by vibrations, can be avoided such that the control of the welding wire can be done very precisely.

The invention is explained in more detail using the following exemplary embodiment with reference to the schematic drawings. For this purpose

Fig. 1: shows the production of the weld metal in the upper sheet by means of a metal inert-gas-shielded welding device in a perspective view, and

Fig. 2: shows the penetration of the overlapping sheets in a perspective view.

According to Fig. 1, a commercially available metal inert-gas-shielded welding device for metal inert gas welding (MIG) is used for the method. This includes a welding torch 4, a welding wire 3 and a wire feed facility (not shown).

The overlapping sheets consist of the upper sheet 1 and the lower sheet 2. The upper sheet 1 is a thin sheet with a sheet thickness of 1.2 mm made of the steel material 22MnB5; the lower sheet 2 is also a thin sheet with a sheet thickness of 1.4 mm made of an AlMgSi alloy of the alloy group 6000. The upper sheet is provided with a hot-dip aluminium coating made of 90 m-% Al and 10 m-% Si. The welding wire material G3Si1 (SG 2) with a wire diameter of 1.0 mm is used as the welding wire 3.

With the aid of the spacer 8, the welding torch 4 is stopped at a spacing of 10 mm above the upper sheet 1 at the joining site, wherein the welding wire 3 is aligned perpendicular to the sheet plane. Then, the joining site is supplied with the shielding gas 5 of argon.

The welding wire 3 is delivered in the direction of the upper sheet 1 by means of a wire feed facility with a wire feed speed of 14 $m \cdot min^{-1}$. The arc 6 is started when the welding wire 3 approaches the upper sheet 1, wherein the welding wire 3 and the upper sheet 1 are melted by the heating in the region of the arc 6. Thereby, a trough-shaped puddle of molten weld metal 7 is formed.

As a result of the continuous wire feed, the arc 6 dips - as shown in Fig. 2 - into the molten weld material 7 and the arc plasma drives the molten weld material forward in front of the wire tip of the welding wire 3. As a result of the pressure thereby exerted onto the lower sheet 2, this is melted through and the molten weld metal 7 is pressed through the breakthrough formed in the lower sheet 2.

The welding wire 3, which continuously melts in the arc 6, fills-up the joining site with the weld material 7.

After a welding time of 0.5 s, the arc 6 is switched off and the weld metal 7 solidifies. Thereby, the drop-shaped closing head 7.3, the performed head 7.1 and the shank 7.2 are formed. In addition to the material-fit, this shape of the weld metal 7 creates the form-fit that is comparable to a precisely fitting steel rivet.

List of the reference symbols used

1	Upper sheet
2	Lower sheet
3	Welding wire
4	Welding torch
5	Shielding gas
6	Arc
7	Weld metal
7.1	Performed head
7.2	Shank
7.3	Closing head
8	Spacer

Patentkrav

1. Svejsefremgangsmåde til sammenføjning af overlappende plader, i det mindste omfattende en overplade (1) og en underplade (2), ved hjælp af en metalbeskyttelsesgassvejseindretning, omfattende en svejsebrænder (4) med en svejsetråd (3) og en trådtransportanordning til trådfremføring af svejsetråden (3), som i denne forbindelse er styret bevægeligt i sin længderetning inde i svejsebrænderen (4), omfattende fremgangsmådetrinnene:

a) placering af svejsebrænderen (4) og dermed svejsetråden (3) på et forudbestemt sammenføjningssted med forudbestemt afstand over overpladen (1), hvor svejsetråden (3) er orienteret i en vinkel på 90 ± 30° i forhold til overpladens (1) pladeplan;

b) levering af svejsetråden (3) i retning af overpladen (1) ved hjælp af trådtransportanordningen med en variabel justerbar trådfremførings-hastighed;

og **kendetegnet ved** de yderligere fremgangsmådetrin:

c) smeltning af overpladen (1) og smeltning af svejsetråden (3) ved hjælp af en mellem overpladen (1) og svejsetråden (3) antændt lysbue (6) under dannelsen af et trugformet smeltebad af smeltet svejsemetal (7);

d) påtrykning af det smeltede svejsemetal (7) på underpladen (2) ved hjælp af svejsetråden (3), hvor den gennemsnitlige trådfremførings-hastighed er i området fra 10 til 40 $m \cdot min^{-1}$, og underpladen (2) gennembrændes under dannelsen af et gennembrud, hvis laterale udstrækning er mindre end det trugformede smeltebad, og yderligere materiale fra underpladen (2) absorberes i det smeltede svejsemetal (7);

f) gennemtrykning af svejsemetallet (7) gennem gennembruddet i underpladen (2) ved hjælp af svejsetråden (3);

g) udfyldning af sammenføjningsstedet med smeltet svejsemetal (7) ved at fortsætte med at smelte pladerne (1, 2) og svejsetråden (3) ved hjælp af lysbuen (6); og

h) frakobling af lysbuen (6) og trådtransportanordningen efter en bestemt svejsetid, hvor svejsemetallet (7) størkner under dannelsen af et sæthoved (7.1) i overpladeområdet (1), af et dråbeformet lukkehoved (7.3) på overfladen af underpladen (2), som vender væk fra svejsebrænderen (4), og af et skaft (7.2) inde i underpladen (2), hvis laterale udstrækning er mindre end sæthovedets (7.1) og lukkehovedets (7.3).

2. Svejsefremgangsmåde ifølge krav 1, **kendetegnet ved, at** svejsetiden er i området fra 0,1 til 1,0 sekunder.

3. Svejsefremgangsmåde ifølge krav 1 eller 2, **kendetegnet ved, at** en eller flere mellemplader indsættes mellem over- og underpladerne (1, 2).

4. Svejsefremgangsmåde ifølge et af kravene 1 til 3, **kendetegnet ved, at** pladetykkelsen af overpladen, underpladen og mellempladerne er mindre end 3 mm.

5. Svejsefremgangsmåde ifølge et af kravene 1 til 4, **kendetegnet ved, at** sammenføjningsstedet forsynes med en beskyttelsesgas (5) ved hjælp af metalbeskyttelsesgassvejseindretningen, hvor argon, helium eller nitrogen anvendes som inert beskyttelsesgas, eller kuldioxid eller en gasblanding indeholdende kuldioxid anvendes som aktiv beskyttelsesgas (5).

6. Svejsefremgangsmåde ifølge et af kravene 1 til 5, **kendetegnet ved, at** svejsetråden (3) og overpladen (1) består af et metal eller en metallegering med højt smeltepunkt, og underpladen (2) består af et metal eller en metallegering med lavt smeltepunkt.

7. Svejsefremgangsmåde ifølge krav 6, **kendetegnet ved, at** svejsetråden (3) og overpladen (1) består af en jern-, nikkel-, titan- eller molybdænbaseret metallegering.

8. Svejsefremgangsmåde ifølge krav 6, **kendetegnet ved, at** underpladen (2) består af en aluminium-, magnesium-, kobber-zink- eller kobber-tinbaseret metallegering.

9. Svejsefremgangsmåde ifølge et af kravene 1 til 8, **kendetegnet ved, at** svejsebrænderen standses ved en forudbestemt afstand fra overfladen af overpladen, der vender mod svejsebrænderen, ved hjælp af en afstandsholder (8) af metalbeskyttelsesgassvejseindretningen.

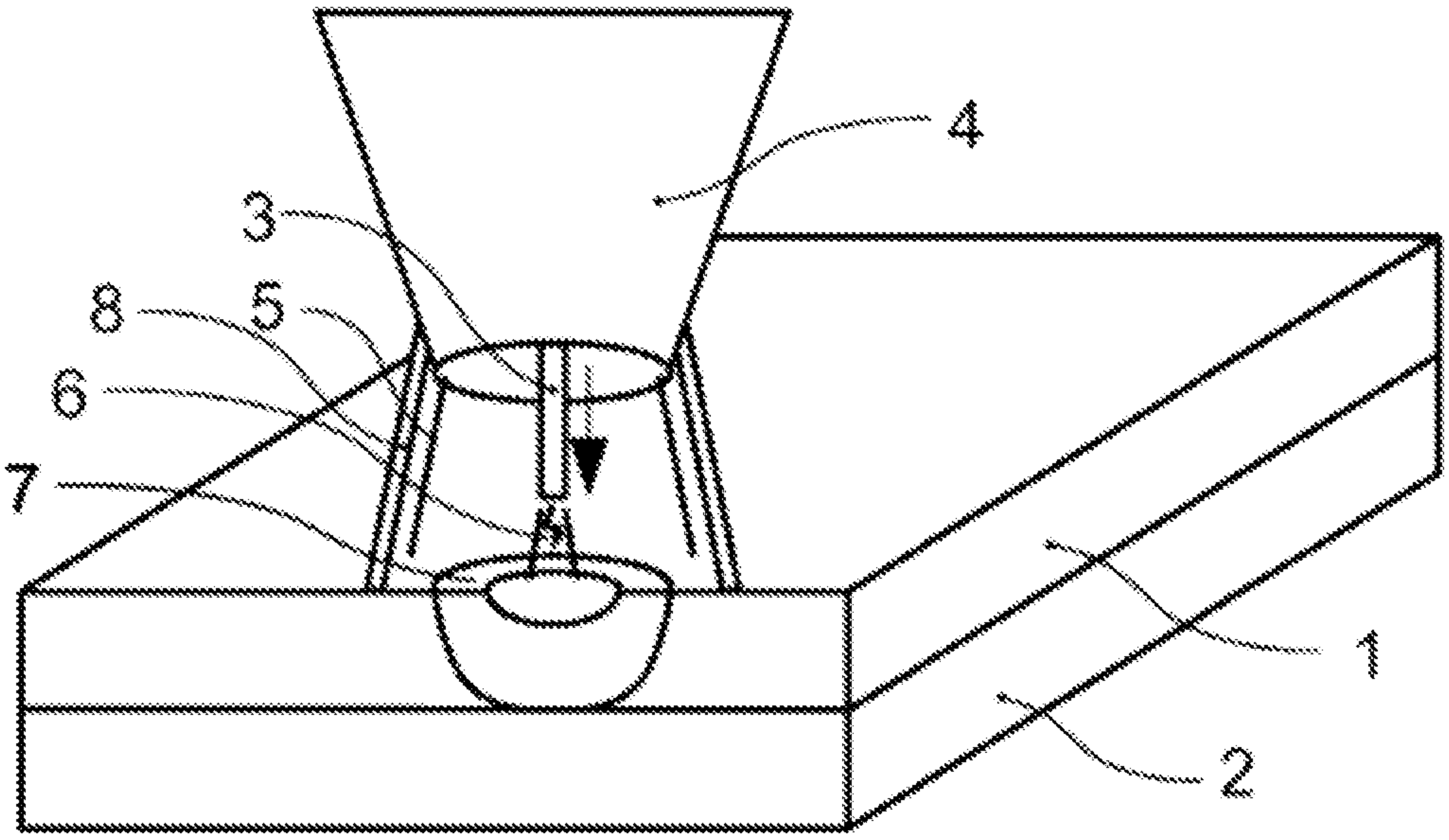

Fig. 1

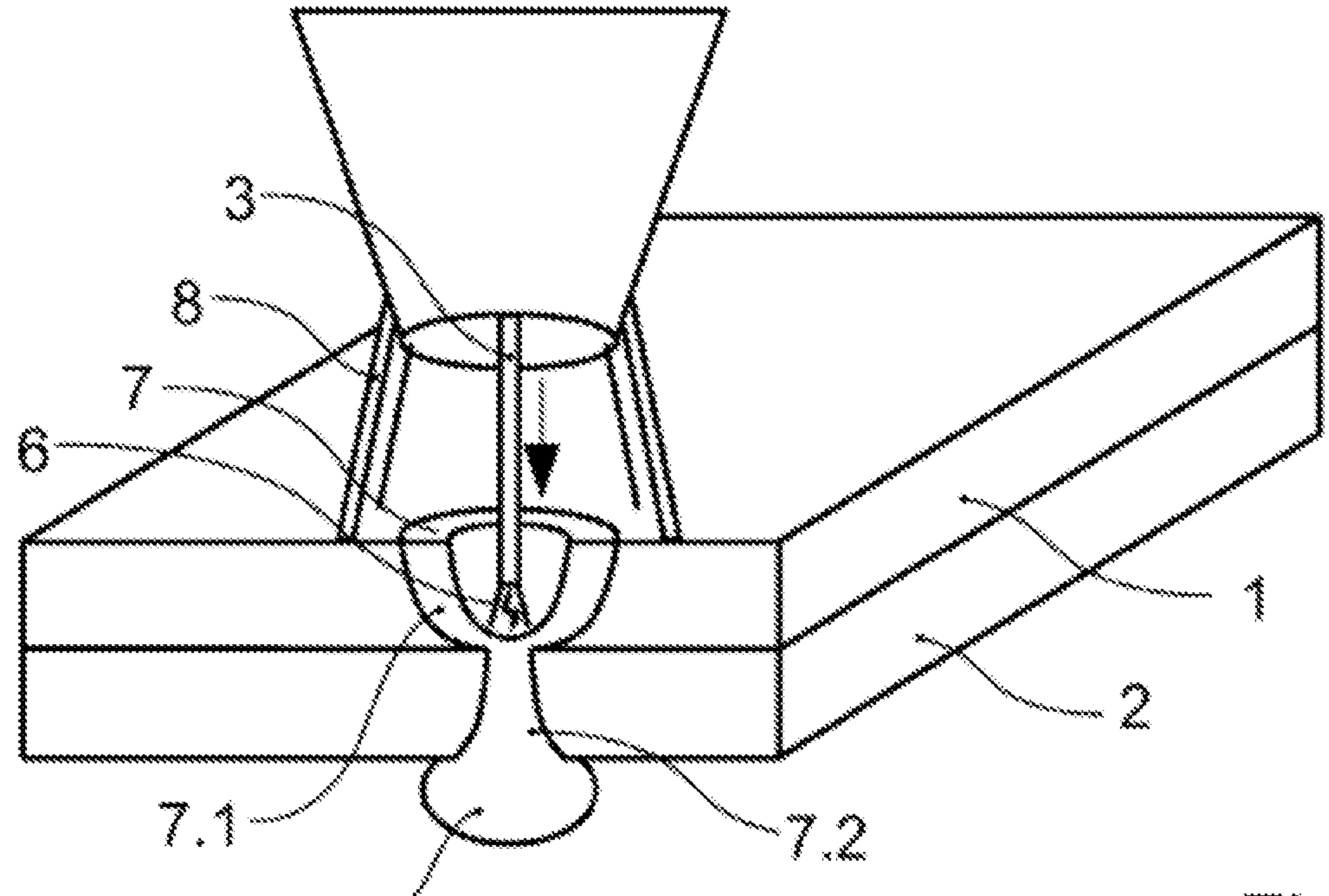

Fig. 2