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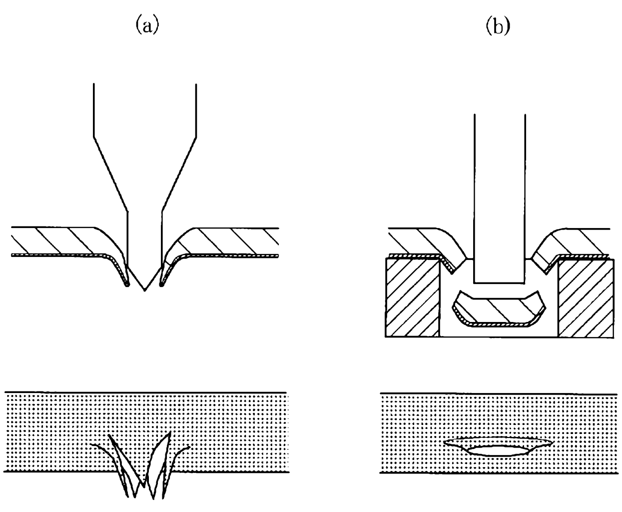
(54) Title: METHOD FOR WELDING COATED STEEL PLATE

(54) 発明の名称 : 塗装鋼板の溶接方法

[図1]



(57) Abstract: Provided is a method for welding coated steel plates in which a metal portion of a metal plate having one surface coated with an insulating film is punched from the other surface having no insulating film with a punch having a flat end and a die paired therewith, whereby the lower end of the metal portion on the inner surface of the punched hole is exposed at the surface coated with the insulating film. The exposed portion is then brought into contact with another metal plate, allowing an electric current to pass therethrough for jointing by resistance welding.

(57) 要約: 片面が絶縁皮膜で覆われている金属板に先端形状が平らなパンチとそれと対になるダイで絶縁皮膜がない側から金属体を打ち抜くことによって打ち抜き孔内面下端部の金属体を絶縁皮膜形成面側に露出させ、当該露出部を接合させる金属体に接触させて通電し、抵抗溶接する。

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DESCRIPTION

METHOD FOR WELDING COATED STEEL PLATE

TECHNICAL FIELD

[0001] The present invention relates to a method for joining the insulating film-coated side of a metal plate coated on one side with an insulating film to a metal workpiece in contact therewith by a resistance welding technique that involves passing an electric current through the insulating film-coated side of the metal plate and the metal workpiece.

BACKGROUND ART

[0002] Insulating films such as coats of paint are used in a variety of ways in many fields to enhance the corrosion resistance and outward appearance of metal structures.

Methods for providing insulating films include cases in which the structure is fabricated using unmodified metal plates and an insulating film is applied in a subsequent step, and cases in which the structure is constructed using insulating film-coated metal plates. In cases where the structure is fabricated using unmodified metal plates and an insulating film is applied in a subsequent step, resistance welding is commonly used as the joining method required for assembly of the plates.

[0003] However, the cost of the subsequent step of applying an insulating film ends up being higher than the cost of assembling metal plates to which an insulating film has already been applied. Accordingly, it is desired to assemble structures using metal plates to which an insulating film has already been applied. In such cases, owing to the presence of the insulating film through which an electric current will not pass, resistance welding cannot be carried out. Hence, a joining method which entails the use of rivets, bolts and nuts, or screws is often employed. However, with joining methods that use such subsidiary materials, the weight of the structure obtained by joining increases, and the cost of the structure rises due to the additional cost of the subsidiary materials. In this connection, methods for joining even metal workpieces to which an insulating film has been applied are being contemplated.

[0004] For example, Patent Document 1 discloses, in a case where metal workpieces to be joined together have an insulating film on one surface side thereof, a method for joining the metal workpieces by pressing them together from above and below with an electrode having a protrusion on the side of the two metal workpieces to be joined where the film is located and with an opposing electrode so as to pierce the film, and resistance-welding the metal workpieces by passing an electric current therethrough.

Patent Document 2 discloses, in a case where metal workpieces to be joined together have an insulating film on one surface side thereof, a method for joining the metal workpieces by forming a hole in the film with a die having a protrusion on the side of the two metal workpieces to be joined where the film is located, then pressing the two metal workpieces together from above and below with a pair of electrodes and resistance-welding the metal workpieces by passing an electric current therethrough.

[0005] Patent Document 3 discloses, in a case where metal workpieces to be joined together have an insulating film on one surface to be joined, a method for joining the metal workpieces by forming a hole in the metal workpiece having the film thereon, providing a conical protrusion on the other metal workpiece having no film, pressing the two metal workpieces together from above and below with a pair of electrodes in an overlapping manner such that the protrusion is brought into contact with a place where metal in the hole is exposed, and resistance-welding the metal workpieces by passing an electric current therethrough.

In addition, Patent Document 4 discloses, in a case where metal workpieces to be joined have an insulating film on one surface to be joined, a method for joining the metal workpieces by forming a hole with a tapered die in one of the metal workpieces having a film thereon, pressing the two metal workpieces together from above and below with a pair of electrodes in a manner such that the end portion of the hole in the metal workpiece where the film has been pierced is brought into contact with the other metal workpiece which is electrically conductive, and resistance-welding the metal workpieces by passing an electric current therethrough.

[0006] Patent Document 1: Japanese Patent Application Laid-open No. 2000-263248

Patent Document 2: Japanese Patent Application Laid-open No. H7-9161

Patent Document 3: Japanese Patent Application Laid-open No. H5-154667

Patent Document 4: Japanese Patent Application Laid-open No. 2007-125602

[0007] In the method disclosed in Patent Document 1, the electrode on the side where the insulating film is to be pierced must be an electrode with a protrusion having a tip shape that is sufficiently sharp enough to pierce the film, and the topmost portion of the electrode must come to a small point or a fine line.

Hence, a welding current that rapidly surges as in the case of capacitor-discharge resistance welding cannot be passed through such an electrode, which limits resistance welding to what is achievable with a very small welding current. Moreover, because the minimum force required for resistance welding is applied between the two welding electrodes, the tips of the electrodes are easily damaged or deformed by the welding current and the force applied between the welding electrodes, as a result of which it becomes impossible to pierce the film straight on. The electrodes must therefore be frequently replaced, making it difficult to employ such a resistance welding method in actual welding operations. In cases where the metal workpiece is thin, the electrode tip ends up piercing the metal workpiece on account of the force applied, as a result of which the current flows directly to the metal workpiece without a film, making welding impossible. High-precision control of the force applied is thus required. Moreover, even in cases where there is a film on the surface where the metal workpieces are to be joined, welding cannot be carried out because the electrode tip pierces the metal workpieces and current ends up flowing directly to the metal workpieces without a film.

[0008] In the method disclosed in Patent Document 2, a hole is formed with a die in the film on the surfaces of the metal workpieces to be welded, the metal workpieces are pressed together with electrodes from above and below, and are welded together by passing an electric current therethrough. However, in cases where the film is thick or is highly flexible, even when a hole is formed therein, surface area where the welding electrode contacts the metal inside the film can not be sufficiently obtained, making it difficult to carry out resistance welding by passing an electric current therethrough. Moreover, as in Patent Document 1, in cases where there is a film on the surface where the metal workpieces are to be joined, the inability to pierce through the film makes it impossible to carry out welding.

[0009] The method disclosed in Patent Document 3 is a method wherein a hole is formed with a die in the metal workpiece having a film, a protrusion is provided on the other metal workpiece having no film which is to be joined thereto, the protrusion is brought into contact with a place where metal in the hole on the first workpiece is exposed, and the metal workpieces are joined by passing a current therethrough. In this method, mechanical working must be carried out on both of the two metal workpieces to be joined; the time and labor required to carry out such work on the metal workpieces increases the costs. Moreover, in cases where the metal workpieces are to be joined in a plurality of places, the need to have the positions of all the matching holes and all the protrusions in agreement calls for high-precision working.

[0010] The method disclosed in Patent Document 4 is a method in which a hole is formed with a tapered die in the side of the metal workpiece having a film thereon, the site where the metal lies exposed is brought into contact with a conductive place on the other metal workpiece, and resistance welding is carried out. This approach more or less resolves the problems inherent in above Patent Documents 1, 2 and 3.

However, if the metal workpiece in which the hole is to be formed has a large thickness, rotation must be applied to the machining tool, which necessitates a vertical driving mechanism and a rotational driving mechanism and thus leads to higher equipment costs. In addition, it is widely known that bond strength is proportional to the bond area. Hence, in order to increase bond strength, the hole formed with a tapered tool must be enlarged so as to increase the surface area of contact at an electrically conductive place on the other metal workpiece to be joined therewith.

[0011] However, when the hole formed with a tapered tool is enlarged beyond a certain degree, the hole ends up splitting as shown in FIG. 1A. This not only does makes it impossible to increase the surface area of contact, it also leads to excessive concentration of the current at the sharp split ends of the hole when a current is passed through, generating sparks and making joining difficult to achieve. Moreover, to enlarge the surface area of contact, the height of the protrusion on the tapered tool becomes larger. When joining has been carried out with a high protrusion, an amount of molten metal corresponding to the height of the protrusion remains between the two joined metal workpieces, resulting in the formation of a gap therebetween. Increasing the electrode force during joining causes the molten metal to be pushed out during joining, enabling a gap-free joint to be formed. However, when the electrode force is high, the surface area of contact becomes too large and the voltage must also be increased, as a result of which the insulating film is damaged due to heat input by the high voltage.

SUMMARY OF THE INVENTION

[0012] The present invention was conceived in order to resolve such problems. The object of at least embodiments of the invention is to seek to provide a method for joining the insulating film-coated surface of a metal plate that is coated on one surface with an insulating film and a surface in contact therewith by making both surfaces conductive and resistance-welding the two workpieces.

[0013] In order to achieve this object, the inventive method for welding coated steel plates includes: punching a metal workpiece in the form of a metal plate coated on one side with an insulating film, using a punch having a flat tip shape and a die paired therewith, from the side of the metal plate without an insulating film so as to form a punched hole in the plate and thereby exposing, on the insulating film-coated side of the metal plate, metal at a bottom end of an inside wall of the punched hole; and bringing the exposed metal into contact with another metal workpiece to be joined to the metal plate, and passing an electric current through the area of contact between the workpieces so as to bond the workpieces together by resistance projection welding.

The punch and die for punching through the metal plate so as to expose, on the insulating film-coated side of the metal plate, the metal at the bottom end of the inside wall of the punched hole preferably have punching cross-sectional shapes which are circular.

[0014] The punch preferably used has a tip that is flat, a cylindrical portion which extends perpendicularly to the flat face, and a tapered portion that is continuous with the cylindrical portion; or has a tip that is flat, a cylindrical portion which extends perpendicularly to the flat face, a tapered portion that is continuous with the cylindrical portion, and a large-diameter cylindrical portion that is continuous with the tapered portion.

Also, the clearance between the punch and the die when the metal plate is punched, as defined by formula (1) below, is set to preferably from 60 to 320%, and more preferably from 60 to 100%:

$$\text{clearance}\ (\%) = \{(Dd - Dp)/2\}/t \times 100 \qquad (1).$$

In formula (1), Dd is the die diameter (mm), Dp is the punch diameter (mm), and t is the thickness of the metal plate (mm).

[0015] One advantage of the invention is that the insulating film-coated side of a metal plate coated on one side with an insulating film such as a coat of paint can be made electrically conductive with a side of another metal workpiece in contact therewith, allowing a metal structure to be easily constructed by joining both workpieces using merely a resistance-welding technique. Moreover, a large surface area of contact for passing current therethrough can be secured, making it possible to then stably carry out resistance welding.

As a result, high-quality metal structures having excellent corrosion resistance and appearance, and also high bond strength can be provided at low cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1A is a diagram depicting a conventional method for forming a projection by punching, and FIG. 1B is a diagram depicting the use of the inventive method for forming a projection by punching.

FIG. 2 is a diagram showing the relationship between the diameter of a punch and the diameter of a die for forming a projection.

FIG. 3 is a diagram depicting a method for enlarging the surface area of annular metal exposure beyond an insulating film.

FIG. 4 is a schematic diagram depicting the projection welding method used in the examples of the invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0017] If it were possible for a metal workpiece provided with an insulating film such as a coat of paint for the purpose of enhancing corrosion resistance and appearance to be resistance welded while leaving the insulating film thereon, this would enable metal structures having excellent corrosion resistance and appearance to be furnished at a low cost.

The inventors have thus conducted extensive investigations on ways of having the insulating film-coated side of a metal plate coated on one side with an insulating film be electrically conductive with a side of another metal workpiece in contact therewith, and thereby joining the two together by resistance welding.

[0018] To enable the insulating film-coated side of a metal plate to be resistance welded to the side of another metal workpiece, the insulating film either must be made as thin as possible or must be pierced so that electricity passes through.

Making the insulating film as thin as possible requires that the metal plate also be made thin, resulting in a large decrease in the strength of the structure of joined metal plates.

Methods for piercing through the insulating film include, as can be seen in Patent Document 4 above, the technique of pushing a tool having a pointed tip into the film-coated metal workpiece so as to form a hole, and thereby exposing the metal.

However, when this technique is used to try to form a hole larger than a certain size, the hole splits as shown in FIG. 1A, resulting in the exposure of metal having a sharply pointed shape. When current is passed through, the current concentrates excessively at the sharply split ends of the hole, generating sparks and making joining difficult to achieve.

[0019] Because problems such as these arise when a tool having a pointed tip is used, investigations were carried out on a method for forming a hole by using a cylindrical, flat-tipped punch and die to punch through the metal plate from the side of the plate not coated with an insulating film, and thereby removing the insulating film.

However, although merely punching through the plate using a cylindrical flat-tipped punch tip and die does push aside the insulating film, the insulating film ends up remaining at the surface of contact between the plate and the other conductive metal plate to be joined therewith, as a result of which the surface of contact becomes non-conductive. In a conventional punching operation, because the clearance between the punch and the die is relatively small, the "shear drop" or "burr" is relatively small, and so the insulating film ends up remaining at the edges of the punch hole.

[0020] It was thus decided to carry out punching with a die having a diameter that is considerably larger than the diameter of a punch of a punching through mold; that is, under conditions such that the "shear drop" or "burr" shape become larger.

By punching through the plate under such conditions, the "shear drop" or "burr" shape becomes larger as shown in FIG. 1B, resulting in annular exposure of the metal at the end of the punch hole. With annular exposure of the metal, contact of the metal plate with the opposing metal workpiece becomes linear, ensuring a current-conducting area at the surface area of contact which is larger than the point-like contact in the prior art, thus enabling stable resistance welding.

[0021] As for the relationship of the die diameter to the diameter of the punch used, the larger the "shear drop" or "burr" shape formed in the punched hole following punch-through, the better. In other words, it is preferable to make the clearance relatively large. When the "burr" is small, the annular metal that is exposed does not emerge outside of the insulating film, as a result of which contact of the metal plate with the opposing metal workpiece is inadequate. However, if the clearance is too large, the range over which a "shear drop" or "burr" forms due to punch through becomes too wide, making it impossible to fully carry out exposure of the metal.

[0022] In addition, the "shear drop" or "burr" is deformed by the electrode force applied during welding, preventing the electrically conductive portion exposed by punch-through from coming into contact with an electrically conductive portion of the opposing metal workpiece to be joined therewith. Moreover, the punched-out portion of the metal plate remains attached to the punched metal plate and must be removed, such as by a manual or mechanical operation, prior to the application of an electrical current for joining, which is bothersome and leads to increased costs.

[0023] However, it is widely known that, in resistance welding, the bond strength is proportional to the bond area. In cases where a hole has been formed by a mold having a tapered end, if hole enlargement is desired, such enlargement must be carried out by flaring or burring. However, in the present invention, the bond area can be increased by increasing the sizes of the punch and die used for punching through the metal plate.

When a large conductive region is exposed at the protruding end of the metal plate that has been punched through, the joined metal plates will have a high and stable strength. By making the linewidth of the metal ring that is exposed beyond the insulating film at the end of the punched hole even wider, a larger conductive portion can be exposed.

[0024] Although reference should be made to the subsequently described examples for further details, from the standpoint of weldability alone, it is preferable to set the clearance to from 60 to 320%. In order to sever the punched-out portion of the metal plate from the punched metal plate, the clearance must be set to from 60 to 100%.

The clearance is defined by formula (1) below:

$$\text{clearance } (\%) = \{(Dd - Dp)/2\}/t \times 100 \qquad (1).$$

Here, as shown in FIG. 2, Dd is the die diameter (mm), Dp is the punch diameter (mm), and t is the thickness of the metal plate (mm).

[0025] An effective method for exposing a large conductive region is to bend the end face of the punched hole by using a punch that has a portion extending vertically from the tip and is provided thereabove with a taper, and thereby bring a large conductive region into contact with the metal plate to be joined with the punched metal plate.

That is, referring to FIG. 3, a larger conductive region can be brought into contact with the metal plate to be joined therewith by using a punch having a flat tip, a cylindrical portion which extends perpendicularly to the flat tip and a tapered portion continuous therewith to bend the "shear drop" in the area where a hole was formed with the tapered portion and thereby exposing a larger conductive region (FIG. 3 A), or by using a punch having a flat tip, a cylindrical portion which extends perpendicularly to the flat tip, a tapered portion continuous therewith and a large-diameter cylindrical portion continuous with the tapered portion to carry out burring which irons and bends the "shear drop" with a large-diameter cylindrical portion (FIG. 3B).

[0026] Burring as shown in FIG. 3B is effective for enlarging the welding surface area during resistance welding. However, when the amount of ironing becomes larger due to burring, the plate thickness at the protrusion decreases, resulting in a decline in the conductive surface area. As a result, the bond area is reduced, leading to a decline in the bond strength.

Although reference should be made to the subsequently described examples for further details, in cases where burring is carried out with the large-diameter cylindrical portion of a punch having a small-diameter cylindrical portion and a large-diameter cylindrical portion, it is preferable for the ratio of the clearance of the large-diameter cylindrical portion to the clearance of the small-diameter cylindrical portion to be set to 0.9 or less.

However, if the ratio is too low, the region of exposed metal will end up becoming smaller. Hence, it is preferable to set the lower limit to about 0.5.

[0027] Next, preferred forms of resistance welding are described.

It is preferable to employ in resistance welding a capacitor-discharge projection welding process which has short welding time and wherein the time the insulating film is effected by heat is short. As for the method for applying current, if the current is passed by an indirect method where one electrode is pressed against the punched-out projection on one steel plate from above the other electrode is pressed against the other steel plate to be joined to the first steel plate from the same direction as the first electrode, joining without damage to the insulating film is possible.

[0028] As described above, by punching a metal plate coated on one side with an insulating film, using a punch having a flat tip shape and a die paired therewith, from the side of the metal plate without an insulating film, so as to form a punched hole and thus exposing, on the insulating film-coated side of the metal plate, metal at a bottom end of an inside wall of the punched hole, then bringing the exposed metal into contact with another metal workpiece to be joined to the metal plate and passing an electric current through the area of contact between the workpieces, the metal plate and the metal workpiece can be easily joined together by resistance welding.

EXAMPLES

[0029]

Example 1

Primed steel plates composed of hot-dip galvanized steel plates having a length of 70 mm, a width of 40 mm and a thickness of 0.8 mm coated on one side only with an insulating film made of an organic resin were used as the workpieces to be projection welded.

In order to join a surface coated with such a film to a film-free surface, a projection was provided by using punches and dies of various differing clearances to punch a first primed steel plate, from the side without a film, at a primed steel plate bonding place on the side where the film comes up to the bonding area.

The punch diameters (Dp), die diameters (Dd) and clearances used are shown in Table 1. The punches had a flat tip shape and the diameters shown in Table 1.

[0030]

[Table 1]

TABLE 1: THE PUNCHES AND DIES USED, AND THEIR CLEARANCES (EXAMPLE 1)

No.	PLATE THICKNESS t (mm)	PUNCH DIAMETER Dp (mm)	DIE DIAMETER Dd (mm)	CLEARANCE (%)
1	0.80	1.00	1.60	38
2	0.80	1.00	2.00	63
3	0.80	1.00	2.60	100
4	0.80	1.00	3.00	125
5	0.80	1.00	4.00	188
6	0.80	1.00	5.00	250
7	0.80	1.00	6.00	313
8	0.80	1.00	8.00	438

[0031] As shown in FIG. 4, the projection on the primed steel plate that has been punched through was overlapped so as to come into contact with the conductive, film-free surface of a primed steel plate to be joined therewith, and joining was carried out by capacitor-discharge projection welding. An indirect method was employed to apply an electrical current. In this indirect method, one of the electrodes was positioned above the projection, and a second electrode paired therewith was brought into contact, on the same side as the first electrode, with the conductive, film-free surface of a steel plate in which a projection has not been provided and which is to be joined to the first steel plate. Welding was carried out at an electrode force of 0.4 kN and a voltage of 120 V.

Next, the shear strength of the joined structure was measured. The results are shown in Table 2.

[0032]

[Table 2]

TABLE 2: PUNCHED STATE AND MAXIMUM SHEAR LOAD (EXAMPLE 1)

No.	PUNCHED STATE	ELECTRODE FORCE (kN)	VOLTAGE (V)	MAXIMUM SHEAR LOAD (kN)
1	SEVERED	0.4	120	NOT WELDABLE
2	SEVERED	0.4	120	0.75
3	SEVERED	0.4	120	0.81
4	REMAINED ATTACHED	0.4	120	0.7
5	REMAINED ATTACHED	0.4	120	0.69
6	REMAINED ATTACHED	0.4	120	0.64
7	REMAINED ATTACHED	0.4	120	0.68
8	REMAINED ATTACHED	0.4	120	NOT WELDABLE

[0033] In Test No. 1, sparks were generated, which made joining impossible. The reason is thought to be that, because the clearance between the punch and the die was small, the "burr" was small and insulating film remained at the end of the punched hole after punching. Joining could not be carried out in Test No. 8 as well. Here, the reason is presumably that, because the clearance was too large, the scope of the "burr" that formed became large. The "burr" ended up deforming under the electrode force during welding, making it impossible to adequately carry out exposure of the metal.

In the other tests (Tests Nos. 2 to 7), sufficient joining was achieved. In Tests Nos. 4 to 7, fragments of the punched-out metal remained, and were removed prior to pressure bonding.

Also, in Test Nos. 2 to 7, a good appearance was obtained, with no delamination of the film at the bonding place.

It is apparent from these results that, at a clearance in the range of 60 to 320%, a sufficient bond strength and a good appearance with no film delamination can be obtained.

[0034]

Example 2

In the above example, when the clearance was large, fragments of the punched-out metal remained.

Hence, in the present example, the clearance was made smaller and the workpieces were examined for remaining fragments of the punched-out metal.

Using punches and dies of the sizes shown in Table 3, the metal plates were punched in the same way as in Example 1.

Table 4 indicates where remaining fragments of the punched-out metal were present or absent.

From the results, it is apparent that when the clearance was 100% or less, punched-out metal fragments did not remain attached after punching, thus making it possible to carry out projection welding without having to remove such punched-out metal fragments prior to pressure bonding.

When combined with the results from Example 1, it is apparent that at a clearance of 60 to 100%, there is no need to remove punched-out metal fragments, thus enabling projection welding to be easily carried out.

[0035]

[Table 3]

TABLE 3: THE PUNCHES AND DIES USED, AND THEIR CLEARANCES (EXAMPLE 2)

No.	PLATE THICKNESS t (mm)	PUNCH DIAMETER Dp (mm)	DIE DIAMETER Dd (mm)	CLEARANCE (%)
11	0.80	2.15	3.10	59
12	0.80	2.15	3.30	72
13	0.80	2.15	3.50	84
14	0.80	2.15	3.70	97
15	0.80	2.15	3.80	103
16	0.80	2.15	3.90	109
17	0.80	2.15	4.00	116
18	0.80	2.15	4.30	134

[0036]

[Table 4]

TABLE 4: RESIDUAL STATE OF FRAGMENTS OF THE PUNCHED-OUT METAL (EXAMPLE 2)

No.	PUNCHED STATE	REMARKS
11	SEVERED	10 WERE SEVERED OUT OF 10 REPETITIONS
12	SEVERED	10 WERE SEVERED OUT OF 10 REPETITIONS
13	SEVERED	10 WERE SEVERED OUT OF 10 REPETITIONS
14	SEVERED	10 WERE SEVERED OUT OF 10 REPETITIONS
15	SOME REMAINED ATTACHED	8 WERE SEVERED OUT OF 10 REPETITIONS
16	ALL REMAINED ATTACHED	0 WERE SEVERED OUT OF 10 REPETITIONS
17	ALL REMAINED ATTACHED	0 WERE SEVERED OUT OF 10 REPETITIONS
18	ALL REMAINED ATTACHED	0 WERE SEVERED OUT OF 10 REPETITIONS

[0037]

Example 3

It has been explained above that burring as shown in FIG. 3B is effective for increasing the surface area of contact during resistance welding.

Hence, the influences of the small-diameter cylindrical portion clearance and of the large-diameter cylindrical portion clearance were investigated in cases where a punch having a small-diameter cylindrical portion and a large-diameter cylindrical portion is used and burring is carried out with the large-diameter cylindrical portion as shown in FIG. 3B.

Using punches and dies of the sizes shown in Tables 5 and 6, metal plates were punched in the same way as in Example 1.

Next, bonding was carried out in the same way as in Example 1 by projection welding under varying electrode forces and voltages as shown in Table 7.

With regard to the state of the film, under each of these test conditions, no peeling of the film occurred at the bonded places, resulting in a good appearance.

Next, the shear strength of the resulting joined structure was measured. Those results are also shown in Table 7.

The effectiveness of burring is apparent from the results in Table 7.

[0038]

[Table 5]

TABLE 5: PUNCHES AND DIES USED (EXAMPLE 3)

No.	PLATE THICKNESS t (mm)	PUNCH			DIE
		Dp1 (mm)	TAPER ANGLE (°)	Dp2 (mm)	Dd (mm)
21	0.80	1.00	30	1.50	2.55
22	0.80	1.00	30	1.50	3.10
23	0.80	1.00	30	1.50	4.10
24	0.80	2.15	30	2.65	3.70
25	0.80	2.15	30	2.65	4.70
26	0.80	2.00	30	2.20	3.40
27	0.80	2.00	30	2.20	3.40

[0039]

[Table 6]

TABLE 6: CLEARANCES OF PUNCHES AND DIES USED (EXAMPLE 3)

No.	CLEARANCE (%)		CLEARANCE RATIO (LARGE-DIAMETER CYLINDRICAL PORTION/ SMALL-DIAMETER CYLINDRICAL PORTION)
	SMALL-DIAMETER CYLINDRICAL PORTION	LARGE-DIAMETER CYLINDRICAL PORTION	
21	97	66	0.68
22	131	100	0.76
23	194	163	0.84
24	97	66	0.68
25	159	128	0.80
26	88	75	0.86
27	88	75	0.86

[0040]

[Table 7]

TABLE 7: PUNCHED STATE AND MAXIMUM SHEAR LOAD (EXAMPLE 3)

No.	PUNCHED STATE	ELECTRODE FORCE (kN)	VOLTAGE (V)	MAXIMUM SHEAR LOAD (kN)
21	SEVERED	0.4	120	0.80
22	REMAINED ATTACHED	0.4	120	0.94
23	REMAINED ATTACHED	0.4	120	1.02
24	SEVERED	0.4	180	1.47
25	REMAINED ATTACHED	0.4	190	1.6
26	SEVERED	0.4	145	0.83
27	SEVERED	0.4	155	1.1

[0041] Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of common general knowledge in the field.

[0042] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

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CLAIMS

1. A method for welding coated steel plates, comprising:

punching a metal workpiece in the form of a metal plate coated on one side with an insulating film, using a punch having a flat tip shape and a die paired therewith, from a side of the metal plate without an insulating film so as to form a punched hole in the plate and thereby exposing, on the insulating film-coated side of the metal plate, metal at a bottom end of an inside wall of the punched hole; and

bringing the exposed metal into contact with another metal workpiece to be joined to the metal plate, and passing an electric current through the area of contact between the workpieces so as to bond the workpieces together by resistance projection welding.

2. The coated steel plate welding method according to claim 1, wherein the punch and die for punching through the metal plate so as to expose, on the insulating film-coated side of the metal plate, the metal at the bottom end of the inside wall of the punched hole have punching cross-sectional shapes which are circular.

3. The coated steel plate welding method according to claim 1 or 2, wherein the punch used has a tip that is flat, a cylindrical portion which extends perpendicularly to the flat face, and a tapered portion that is continuous with the cylindrical portion.

4. The coated steel plate welding method according to claim 1 or 2, wherein the punch used has a tip that is flat, a cylindrical portion which extends perpendicularly to the flat face, a tapered portion that is continuous with the cylindrical portion, and a large-diameter cylindrical portion that is continuous with the tapered portion.

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5. The coated steel plate welding method according to any one of claims 1 to 4, wherein a clearance between the punch and the die when the metal plate is punched, as defined by formula (1) below, is from 60 to 320%:

$$\text{clearance (\%)} = \{(Dd - Dp)/2\}/t \times 100 \qquad (1),$$

wherein Dd is a die diameter (mm), Dp is a punch diameter (mm), and t is a thickness of the metal plate (mm).

6. The coated steel plate welding method according to any one of claims 1 to 4, wherein a clearance between the punch and the die when the metal plate is punched, as defined by formula (1) below, is from 60 to 100%:

$$\text{clearance (\%)} = \{(Dd - Dp)/2\}/t \times 100 \qquad (1),$$

wherein Dd is a die diameter (mm), Dp is a punch diameter (mm), and t is a thickness of the metal plate (mm).

7. A method for welding coated steel plates substantially as herein described with reference to any one of the embodiments of the invention illustrated in Figures 1B and 2 to 4 of the accompanying drawings and/or examples.

FIG. 1A

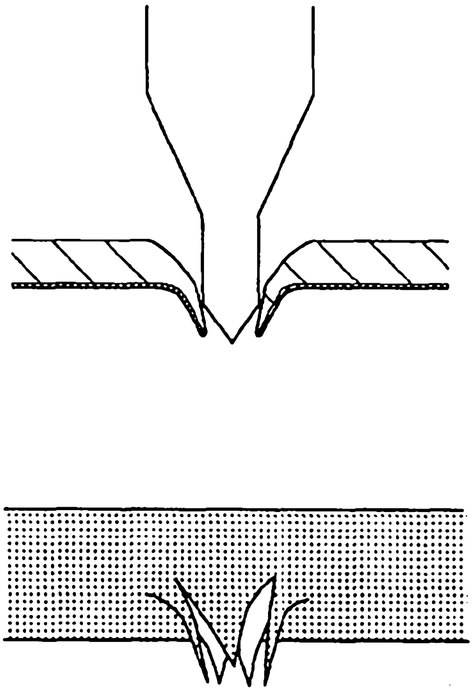

FIG. 1B

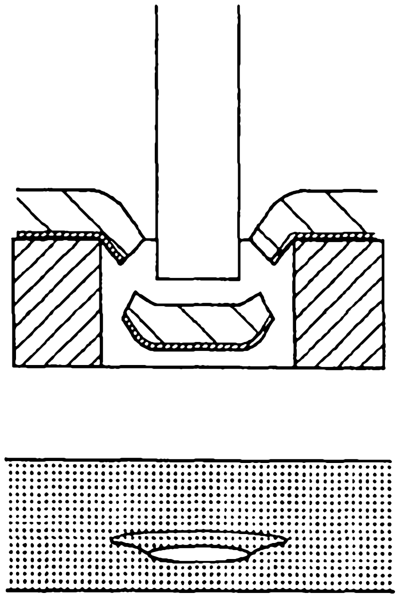

FIG. 2

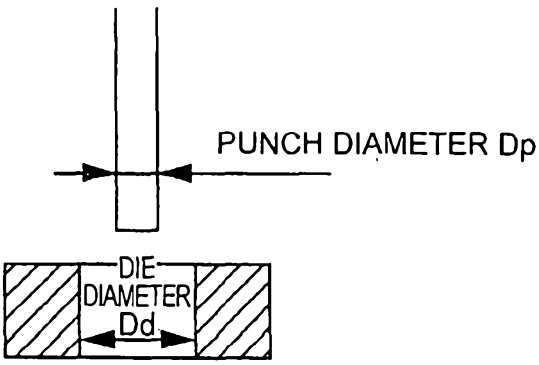

FIG. 3A

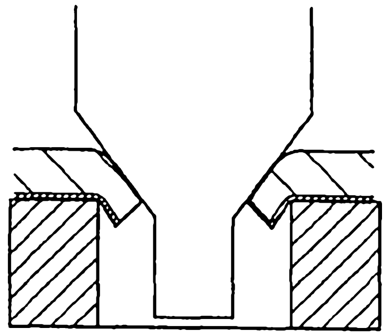

FIG. 3B

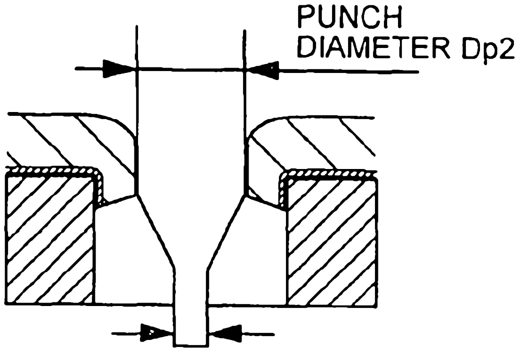

FIG. 4