SHEET SHEARING METHOD

Provided is a method of shearing a thin plate with high quality without a need for narrowing a clearance by precision machining. The method comprises: placing a thin plate (1) having at least one non-metal layer (1b), between a punch (3) and a die (2) having a shearing hole (2a); and relatively moving the punch (3) toward and with respect to the shearing hole (2a) to thereby shear the thin plate (1), wherein the relative movement of the punch (3) is stopped to complete the shearing, before the punch (3) penetrates through the thin plate (1) and becomes fitted into the shearing hole (2a).
DESCRIPTION

TECHNICAL FIELD

[0001] The present invention relates to a method of shearing a thin plate, and more specifically to a method for forming a product by shearing a thin plate with a thickness of about 0.5 mm or less, which is made of a metal or prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer.

BACKGROUND ART

[0002] As a technique for forming a product from a thin plate, a method of punching (blanking) a thin plate using a forming tool (punch and die) is most common. In the punching (blanking) method, the workpiece plate is subjected to shearing by placing a workpiece plate on a die having a punch hole, and moving a punch disposed just above the punch hole downwardly to allow a distal end of the punch to be fitted into the punch hole. In some cases, the punch and the die are disposed upside down, i.e., the punch is disposed just below the die, and the die is moved instead of the punch.

[0003] In regard to conditions for the punching, considerable researches have heretofore been made. For example, the following Non-Patent Document 1 discloses an adequate relationship between a thickness of a workpiece plate, and a gap between a punch and a die (punch hole) for punching the workpiece plate (the gap will hereinafter be referred to simply as “clearance”). In the Non-Patent Document 1, an adequate clearance is described as about 5 to 10% of the thickness of the workpiece plate.

[0004] According to this relationship between the thickness of the workpiece plate and the clearance, when the workpiece plate has a thickness of 1 mm, the clearance is in the range of about 50 to 100 μm. As long as the clearance is such a value, it is easy to fabricate a forming tool, etc. However, when the workpiece plate has a smaller thickness, e.g., a thickness of 20 μm, the adequate clearance is reduced to 1 to 2 μm, so that a high level of fabrication technique, such as precision machining, is required for a forming tool, which leads to a problem of an increase in cost.

[0005] Moreover, a punching operation using a forming tool fabricated to have a narrowed clearance involves other problems. One problem is a reduction in usable life of the forming tool due to wear of the punch and the die. Specifically, a narrower clearance leads to a higher frequency of contact between the punch and the die in elastic deformation ranges thereof, which accelerates wear thereof. Further, if the punch and the die are deformed beyond the elastic deformation ranges during the contact therebetween, a problem of chipping will also occur.

[0006] Another major problem is a problem with debris to be generated from a workpiece plate during punching. This problem becomes prominent when the workpiece plate is a laminated plate comprised of a metal layer and a non-metal layer. Debris generated from a workpiece plate is trapped between the punch and the die, which causes various problems, such as a problem of an increase in force required for punching, and a problem of an increase in frequency of cleaning required for the punch and the die. Moreover, the debris is likely to cause breakage of the forming tool.

[0007] The conventional punching method has another problem. Specifically, along with punching of a workpiece plate, particularly a metal plate, depending on its compatibility with a forming tool, adhesion of the workpiece plate is likely to occur in a punch. It is possible to prevent the adhesion problem to some extent by coating a punch and a die with ceramics, DLC (Diamond-Like Carbon) or the like. However, in a forming tool having a narrow clearance, only a temporary effect can be obtained because large wear occurs in a punch and a die due to a sliding movement therebetween.

[0008] Still another problem is deterioration in quality of an outer edge of a punched-out portion of the workpiece plate (product portion). This is because, after punching the workpiece plate, the punched-out portion is moved to a dead center position of the punch while rubbing against an inner surface of the die, i.e., placed in a rubbing state through until it is separated from the die.

[0009] As above, in shearing based on the conventional punching method, various problems occurs, particularly, when a workpiece plate has a small thickness.

PRIOR ART DOCUMENTS


SUMMARY OF THE INVENTION

[0012] In view of the above various problems involved in shearing based on the conventional punching method, it is an object of the present invention to provide a method capable of shearing a thin plate with high quality over a long period of time, and significantly excellently shearing a thin plate based on a low-cost forming tool and a low-cost process, without the necessity to subject a forming tool for use in the shearing to precision machining.

[0013] Through various researches on shearing of thin
plates, the inventor found that, in a thin plate prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, the thin plate is fully sheared before a punch penetrates through the thin plate and becomes fitted into a shearing hole of a die.

The present invention has been made based on the above finding. Specifically, the present invention provides a method of shearing a thin plate prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer. The method comprises: placing the thin plate between a punch and a die having a shearing hole; and relatively moving the punch toward and with respect to the shearing hole to thereby shear the thin plate, wherein the relative movement of the punch is stopped to complete the shearing, before the punch penetrates through the thin plate and becomes fitted into the shearing hole.

As above, in the present invention, the punch is not fitted into the die, so that it is not necessary to severely adjust a clearance as in the conventional punching method designed to allow the punch to be fitted into the die. Thus, the clearance may be set to a zero clearance, or a minus clearance in which an outer diameter of the punch is set to be greater than an inner diameter of the die, as well as an usual plus clearance. In other words, in the present invention, it is not necessary to severely adjust a clearance based on precision machining of a forming tool (punch and die), so that it becomes possible to easily fabricate the forming tool and reduce a fabrication cost of the forming tool.

In addition, based on the feature that the punch is not fitted into the die, each of the punch and the die becomes less likely to be worn, which provides extended usable life of the forming tool. Further, a displacement of a sheared portion of a workpiece plate is reduced, and thereby an amount of debris to be generated is reduced. The conventional method also has a problem that, along with a vertical movement of the punch, a metal portion of a workpiece plate in contact with the punch adheres to the punch. It is difficult to remove the adhered metal component. If it is tried to remove the adhered metal component by rubbing or scraping, or using chemicals, a surface of the punch will have scars, or higher roughness, or alteration due to corrosion. Moreover, the adhesion phenomenon occurs after 100 shots at the latest, or after only 5 to 10 shots at the earliest. In contrast, in the method of the present invention, the shearing can be performed without bringing the punch into direct contact with a metal portion of a workpiece plate, so that it becomes possible to prevent the workpiece plate from adhering to the punch.

Thus, a shearing state can be excellently maintained, and the thin plate can be sheared with high quality. As for a forming tool, there is no need to fabricate a forming tool with a maximally narrowed clearance which causes difficulty in fabrication and leads to a high cost, and therefore there is no need to take a high cost for fabrication of a forming tool.

Meanwhile, in the technical field of punching (blanking), there has been known a method of punching a workpiece plate by subjecting the workpiece plate to half blanking in one direction, and then subjecting the workpiece plate to reversed blanking, instead of punching the workpiece plate by a single punching operation (see, for example, JP 2004-167547A and JP 2001-300647A). The shearing method of the present invention is essentially different from the conventional half blanking/reversed blanking technique, in that the shearing method is designed to fully shear a workpiece plate by a single shearing operation.

Preferably, in the present invention, the punch is stopped at a position corresponding to a depth in the thin plate which is equal to or greater than the thickness of the thin plate stack. If the punch is stopped below the thickness of the thin plate stack, the thin plate stack is incompletely sheared, resulting in a difficulty in shearing the thin plate stack at a high quality.

In addition, the invention is also preferably applied to a thin plate formed by subjecting a plurality of the thin plates to shear in the same manner as in the present invention. To this end, the punch is preferably positioned at a depth corresponding to a total thickness of the plurality of thin plates. Particularly, the punch is preferably positioned at a depth corresponding a depth in the thin plate stack which is equal to or greater than a total thickness of the non-metal layers of the thin plate stack (a sum of respective thicknesses of the metal layers in the plurality of staked thin plates) and equal to or less than a total thickness of the non-metal layers of the thin plate stack (a sum of respective thick-
nesses of the non-metal layers in the plurality of stacked thin plates).

[0021] In addition to the shearing using the punch and the die, the shearing method of the present invention can also be applied to shearing using a die cutter and an anvil roll. Specifically, the present invention provides a method of shearing a thin plate prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer. The method comprises: inserting the thin plate between a die cutter provided with a convex push-cutting blade on a surface thereof, and an anvil roll provided with a shearing recess at a position corresponding to the convex push-cutting blade; and rotating the press roll to press the thin plate toward the shearing recess of the anvil roll to thereby shear the thin plate, wherein the thin plate is sheared without causing the convex push-cutting blade of the die cutter to penetrate through the thin plate and become fitted into the shearing recess of the anvil roll. This shearing method also provides the same effects as those of the shearing using the punch and the die. In other words, the thin plate is fully sheared before the convex push-cutting blade of the die cutter penetrates through the thin plate and become fitted into the shearing recess of the anvil roll.

[0022] Preferably, in the shearing method using the die cutter and the anvil roll, the convex push-cutting blade of the die cutter is thrust to a position corresponding to a depth in the thin plate which is equal to or greater than the thickness of the metal layer and equal to or less than the total thickness of the one or more non-metal layers.

[0023] Further, in order to more reliably shear the thin plate (i.e., workpiece plate) in the shearing method using the die cutter and the anvil roll, an intermediate plate having at least one non-metal layer may be inserted between the die cutter and the thin plate. Based on using the intermediate plate in the above manner, the thin plate can be more reliably sheared by a pressing effect arising from plastic flow of the intermediate plate. Preferably, in this case, the convex push-cutting blade of the die cutter is thrust to a position corresponding to a depth in a combination of the intermediate plate and the thin plate which is equal to or greater than a total thickness of the metal layers of the thin plate and equal to or less than a total thickness of the one or more non-metal layers of the thin plate and the intermediate plate.

[0024] In the present invention, in place of the die cutter provided with the convex push-cutting blade on a surface thereof, a press roll devoid of the convex push-cutting blade may be used. Specifically, the present invention provides a method of shearing a thin plate prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer. The method comprises: inserting the thin plate between a press roll, and an anvil roll provided with a shearing recess; and rotating the press roll to press the thin plate toward the shearing recess of the anvil roll to thereby shear the thin plate, wherein an intermediate plate having at least one non-metal layer is inserted between the thin plate and the die cutter, and the thin plate is sheared without pressing the thin plate into the shearing recess of the anvil roll beyond a thickness of the thin plate. In this shearing method, the thin plate is fully sheared before the thin plate is fully pressed into the shearing recess of the anvil roll. Preferably, in this shearing method, the thin plate is pressed to a position corresponding to a depth in the shearing recess of the anvil roll which is equal to or greater than a total thickness of the metal layer and equal to or less than a total thickness of the one or more non-metal layers of the thin plate.

[0025] The shearing method using the die cutter or press roll and the anvil roll, a thin plate stack formed by stacking a plurality of the thin plates on each other may be inserted between the die cutter or press roll and the anvil roll, to simultaneously shear the plurality of stacked thin plates. Specifically, in the shearing method using the die cutter and the anvil roll, the thin plate stack is inserted between the die cutter and the anvil roll, and all of the thin plates are sheared without causing the convex push-cutting blade of the die cutter to penetrate through the thin plate stack and become fitted into the shearing recess of the anvil roll. Preferably, in this case, the convex push-cutting blade of the die cutter is thrust to a position corresponding to a depth in the thin plate stack which is equal to or greater than a total thickness of the metal layers of the thin plate stack and equal to or less than a total thickness of the non-metal layers of the thin plate stack. When the intermediate plate is used in combination, it is preferable that the convex push-cutting blade of the die cutter is thrust to a position corresponding to a depth in a combination of the intermediate plate and the thin plate stack which is equal to or greater than a total thickness of the metal layers of the thin plate stack and equal to or less than a total thickness of the non-metal layers of the thin plate stack.

[0026] On the other hand, in the shearing method using the press roll and the anvil roll, the thin plate stack is inserted between the press roll and the anvil roll, and the intermediate plate having at least one non-metal layer is inserted between the thin plate stack and the press roll, whereafter the thin plate stack is sheared without pressing the thin plate stack into the shearing recess of the anvil roll beyond a thickness of the thin plate stack. Preferably, in this case, the thin plate stack is pressed to a position corresponding to a depth in the shearing recess of the anvil roll which is equal to or greater than a total thickness of the metal layers of the thin plate stack and equal to or less than a total thickness of the non-metal layers of the thin plate stack.

[0027] In the present invention, in the shearing method using the press roll and the anvil roll, a surface of the press roll may be coated with a layer including at least one non-metal layer. Specifically, the present invention provides a method of shearing a thin plate which is made of a metal or prepared by laminating one or more non-
metal layers on one or respective ones of opposite surfaces of a metal layer. The method comprises: inserting the thin plate between a press roll having a surface coated with a layer including at least one non-metal layer, and an anvil roll provided with a shearing recess; and rotating the press roll to press the thin plate toward the shearing recess of the anvil roll to thereby shear the thin plate, wherein the thin plate is sheared without pressing the thin plate into the shearing recess of the anvil roll beyond a thickness of the thin plate. Preferably, in this shearing method, the thin plate is pressed to a position corresponding to a depth in the shearing recess of the anvil roll which is equal to or greater than a thickness of the metal layer and equal to or less than a total thickness of the one or more non-metal layers of the thin plate. In this shearing method, when a plurality of the thin plates are stacked on each other to form a thin plate stack, and the thin plate stack is inserted between the press roll and the anvil roll and sheared, the thin plate stack is sheared without pressing the thin plate stack into the shearing recess of the anvil roll beyond a thickness of the thin plate stack. Preferably, the thin plate stack is pressed to a position corresponding to a depth in the shearing recess of the anvil roll which is equal to or greater than a total thickness of the metal layers of the thin plate stack and equal to or less than a total thickness of the non-metal layers of the thin plate stack.

[0028] As mentioned above, the shearing method of the present invention is applied to a thin plate prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer. However, the shearing method of the present invention may also be applied to a thin plate made of a metal. Specifically, in a shearing method using a punches and a die having a shearing hole, a thin plate made of a metal is placed between the punch and the die, and the punch is relatively moved toward and with respect to the shearing hole to thereby shear the thin plate, wherein an intermediate plate having at least one non-metal layer is placed between the thin plate and the punch, and the relative movement of the punch is stopped to complete the shearing of the metal plate, before the punch penetrates through the intermediate plate. Preferably, in this case, the relative movement of the punch is stopped at a position corresponding to a depth in a combination of the thin plate and the intermediate plate which is equal to or greater than a thickness of the thin plate and equal to or less than a thickness of the intermediate plate.

[0029] In a shearing method using a die cutter provided with a convex push-cutting blade on a surface thereof and an anvil roll provided with a shearing recess at a position corresponding to the convex push-cutting blade, a thin plate made of a metal is inserted between the die cutter and the anvil roll, and the convex push-cutting blade of the die cutter is rotated and pressed toward the shearing recess of the anvil roll to thereby shear the thin plate, wherein an intermediate plate having at least one non-metal layer is inserted between the thin plate and the die cutter, and the thin plate is sheared without causing the convex push-cutting blade of the die cutter to penetrate through the intermediate plate and become fitted into the shearing recess of the anvil roll. Preferably, in this case, the convex push-cutting blade of the die cutter is thrust to a position corresponding to a depth in a combination of the thin plate and the intermediate plate which is equal to or greater than a thickness of the thin plate and equal to or less than a thickness of the intermediate plate.

[0030] In a shearing method using a press roll and an anvil roll provided with a shearing recess, a thin plate made of a metal is inserted between the press roll and the anvil roll, and the press roll is rotated to press the thin plate toward the shearing recess of the anvil roll to thereby shear the thin plate, wherein an intermediate plate having at least one non-metal layer is inserted between the thin plate and the die cutter, and the thin plate is sheared without pressing the thin plate into the shearing recess of the anvil roll beyond a thickness of the thin plate. In a shearing method using a press roll having a surface coated with a layer including at least one non-metal layer, and an anvil roll provided with a shearing recess, a thin plate made of metal is inserted between the press roll and the anvil roll, and the press roll is rotated to press the thin plate toward the shearing recess of the anvil roll to thereby shear the thin plate, wherein the thin plate is sheared without pressing the thin plate into the shearing recess of the anvil roll beyond a thickness of the thin plate. Among the above shearing methods of the present invention, in the shearing method using the die cutter or press roll, the anvil roll and the intermediate plate, in order to allow the intermediate plate to be repeatedly used, the intermediate plate may be formed in an endless configuration, wherein the intermediate plate is inserted between the die cutter or press roll and the thin plate or thin plate stack and then passed and pressed between a pair of rolls, whereby the intermediate plate is re-inserted between the die cutter or press roll and the thin plate or thin plate stack.

[0031] In the present invention, the anvil roll may be formed such that the shearing recess thereof has a peripheral edge region made of a material having hardness greater than that of the remaining region of the anvil roll. This makes it possible to reliably perform the shearing while preventing chiping or the like from occurring in the peripheral edge region of the shearing recess which is a shearing area.

[0032] Further, the anvil roll may have at least two cut-outs provided at respective positions before and after the shearing recess in a rotation direction thereof, with a given distance from the shearing recess. This makes it possible to prevent the thin plate or thin plate stack from being excessively pressed at respective positions before and after the shearing recess and damaged.
The present invention relates to a method of shearing thin plates, such as electrolyte plates for lithium-ion batteries. The method is characterized by high quality shearing at low cost, and involves the use of a metal layer with non-metal layers on either side, allowing for easy shearing and preventing roughening of the sheared surface. Example embodiments are described, each with specific features such as the use of a punch and die set at different orientations to facilitate the shearing process. The first embodiment, illustrated in FIG. 1, employs a metal layer 1a with a non-metal layer 1b to shears a thin plate 1 with a thickness of 180 μm, achieving 17% of the thickness of the workpiece plate. In the second embodiment, FIG. 2 illustrates a shearing method according to a second embodiment of the present invention, showing basic steps of a shearing method according to a first embodiment of the present invention. The third embodiment, FIG. 3, demonstrates a shearing method according to a third embodiment of the present invention, and so on.
to a second embodiment of the present invention. The second embodiment is one example where a plurality of workpiece plates are stacked on each other to form a workpiece plate stack, and then sheared.

[0044] In the second embodiment, each of eight workpiece plates 1 is an electrode plate for a lithium-ion battery, which has a thickness of 180 μm, as with the first embodiment, and they are stacked on each other vertically. Thus, a total thickness of the stacked workpiece plates 1, i.e., workpiece plate stack, is 1.44 mm.

[0045] In the second embodiment, the punch 3 is stopped at a position away from an initial contact position between the punch 3 and an upper surface of the workpiece plate stack (eight stacked workpiece plates 1) by 200 μm, i.e. at a timing when the punch 3 is moved downwardly (in a depthwise direction of the workpiece plate stack) to a position corresponding to a depth equal to 14% of the thickness of the workpiece plate stack. In a test carried out under the above conditions, it was verified that all of the eight workpiece plates 1 are fully sheared.

[THIRD EMBODIMENT]

[0046] FIG. 3 illustrates a shearing method according to a third embodiment of the present invention. The third embodiment is one example where a thin plate made of a metal is sheared using a punch and a die.

[0047] As shown in FIG. 3(a), a thin plate made of a metal, as a workpiece plate 7, is placed on a die 2, and then an intermediate plate 8 having at least one non-metal layer is placed on the workpiece plate 7. In the third embodiment, the workpiece plate 7 is comprised of a titanium plate having a thickness of 20 μm, and the intermediate plate 8 is comprised of a polypropylene plate having a thickness of 150 μm. As a material of the intermediate plate 8, a non-metal layer may be used which is made of one selected from the group consisting of acrylic resin, PET, polycarbonate, bakelite, plastic, fluororesin, epoxy resin, polyurethane, polyvinyl chloride, polyamide, polyethylene, vinyl chloride, hard rubber, paper, glass plate, asphalt and synthetic fiber, as well as polypropylene. Further, a laminated material comprised of two or more of the non-metal layers or a laminated material comprised of the non-metal layer and a metal layer may be used.

[0048] Then, as shown in FIG. 3(b), a punch 3 disposed just above a shearing hole 2a of the die is moved downwardly to shear the workpiece plate 7.

[0049] In the third embodiment, the punch 3 is stopped at a position away from an initial contact position between the punch 3 and an upper surface of the intermediate plate 8 by 40 μm, i.e. at a timing when the punch 3 is moved downwardly (in a depthwise direction of the intermediate plate 8 and the workpiece plate 7) to a position corresponding to a depth which is equal to or greater than the thickness of the workpiece plate 7 (the thin plate made of a metal) and equal to or less than the thickness of the intermediate plate 8, and until before the punch 3 penetrates through the intermediate plate 8. In a test carried out under the above conditions, it was verified that the workpiece plate 7 is fully sheared. A sheared product portion of the workpiece plate can be easily extracted by pushing or sucking it from thereabove or therebelow.

[0050] In the method designed to shear a thin plate made of a metal, through the intermediate plate 8, as in the third embodiment, it is preferable to stop the punch 3 before the punch 3 is moved by a distance equal to the thickness of the thin plate, as the earliest timing, or before the punch 3 penetrates the intermediate plate 8, as the latest timing, after the punch 3 is initially brought into contact with the upper surface of the intermediate plate 8. In other words, it is preferable that a thrust depth after the punch 3 is initially brought into contact with the upper surface of the intermediate plate 8, is set to a value equal to or greater than the thickness of the workpiece plate (thin plate made of a metal) and equal to or less than the thickness of the intermediate plate 8. A prerequisite in this case is that the thickness of the intermediate plate is greater that the thickness of the workpiece plate (thin plate made of a metal).

[FOURTH EMBODIMENT]

[0051] FIG. 4 illustrates a shearing method according to a fourth embodiment of the present invention. The fourth embodiment is one example where the present invention is applied to a shearing method using a die cut roll consisting of a die cutter and an anvil roll. A workpiece plate 1 in the fourth embodiment is the same as that in the first embodiment.

[0052] As shown in FIG. 4, a die cutter 4 has a convex push-cutting blade 4a provided on a surface thereof at a position corresponding to a shearing recess 5a of an anvil roll 5. The workpiece plate 1 is inserted between the die cutter 4 and the anvil roll 5 which are rotating in respective ones of the arrowed directions, and the convex push-cutting blade 4a of the die cutter is rotated and pressed toward the shearing recess 5a of the anvil roll 5 to shear the workpiece plate 1.

[0053] In the fourth embodiment, during the shearing operation, the workpiece plate 1 is sheared without causing the convex push-cutting blade 4a of the die cutter to penetrate through the workpiece plate 1 and become fitted into the shearing recess 5a of the anvil roll, as shown in FIG. 4. In the fourth embodiment, the convex push-cutting blade 4a is thrust to a position where a distal end thereof is located away from an upper surface of the workpiece plate 1 by 20 μm, i.e., a position corresponding to a depth equal to 11% of the thickness of the workpiece plate 1. In a test carried out under the above conditions, it was verified that the workpiece plate 1 is fully sheared in the same manner as that in the first embodiment. A sheared product portion of the workpiece plate can be easily extracted by pushing or sucking it from thereabove or therebelow.

[0054] Although not illustrated, another test was car-
ried out under the following conditions: A workpiece plate stack formed by stacking two workpiece plates 1 on each other is inserted between the die cutter 4 and the anvil roll 5, and the convex push-cutting blade 4a is thrust to a position corresponding to a depth equal to 36% of a thickness of the workpiece plate stack (two stacked workpiece plates 1). As a result, it was verified that all of the eight workpiece plates 1 are fully sheared in the same manner as that in the second embodiment.

Although the fourth embodiment illustrated in FIG. 4 shows one example where the workpiece plate 1 is sheared which is prepared by laminating the two non-metal layers 1b on respective ones of the opposite surfaces of the metal layer 1a, it is also possible to shear a workpiece plate 7 prepared by laminating one non-metal layer on one of opposite surfaces of a metal layer, in the same manner. Preferably, in this case, the workpiece plate is inserted to allow the non-metal layer to come into contact with the die cutter 4.

FIG. 5 illustrates one modification of the fourth embodiment in FIG. 4. In the modified embodiment illustrated in FIG. 5, an intermediate plate 6 having at least one non-metal layer is inserted between the die cutter 4 and the workpiece plate 7. Based on interposing the intermediate plate 6 in this manner, the workpiece plate 7 can be more reliably sheared by a pressing effect arising from plastic flow of the intermediate plate 6.

Specifically, as the intermediate plate 8, a non-metal layer may be used which is made of one selected from the group consisting of acrylic resin, PET, polycarbonate, bakelite, plastic, fluororesin, epoxy resin, polyurethane, polyvinyl chloride, polycarbonate, polyethylene, polypropylene, vinyl chloride, hard rubber, paper, glass plate, asphalt and synthetic fiber. Further, a laminated material comprised of two or more of the non-metal layers or a laminated material comprised of the non-metal layer and a metal layer may be used.

[FIFTH EMBODIMENT]

FIG. 6 illustrates a shearing method according to a fifth embodiment of the present invention. The fifth embodiment is one example where a thin plate made of a metal is sheared using a die cutter and an anvil roll.

As shown in FIG. 6, a die cutter 4 has a convex push-cutting blade 4a provided on a surface thereof at a position corresponding to a shearing recess 5a of an anvil roll 5. In the fifth embodiment, a thin plate made of a metal, as a workpiece plate 7, is inserted between the die cutter 4 and the anvil roll 5 which are rotating in respective ones of the arrowed directions, and an intermediate plate 6 having at least one non-metal layer is inserted between the die cutter 4 and the workpiece plate 7. Then, the convex push-cutting blade 4a of the die cutter is rotated so as to press the workpiece plate 7 toward the shearing recess 5a of the anvil roll 5 through the intermediate plate 6 to shear the workpiece plate 7. During the shearing operation, the workpiece plate 7 is sheared without causing the convex push-cutting blade 4a of the die cutter to penetrate through the intermediate plate 6 and the workpiece plate 7 and become fitted into the shearing recess 5a of the anvil roll.

In the method designed to shear the workpiece plate 7 (thin plate made of a metal) by the die cut roll through the intermediate plate 8, as in the fifth embodiment, it is preferable to set a distance (gap) between the die cutter 4 and the anvil roll 5, based on the same criteria as that in the third embodiment, in such a manner that a thrust depth of the workpiece plate (thin plate made of a metal) and the intermediate plate into the shearing recess 5a of the anvil roll becomes equal to or greater than a thickness of the workpiece plate and equal to or less than a thickness of the intermediate plate. In other words, it is preferable that the distance (gap) between the die cutter 4 and the anvil roll 5 is set to a value equal to or less than [(the thickness of the workpiece plate + the thickness of the intermediate plate) - the thickness of the workpiece plate] and equal to or greater than the thickness of the workpiece plate. A prerequisite in this case is that the thickness of the intermediate plate is greater than the thickness of the workpiece plate (thin plate made of a metal).

According to experimental tests carried out by the inventor, in the fourth and fifth embodiments using the die cutter 4 and the anvil roll 5, it is preferable that an outer peripheral shape of the convex push-cutting blade 4a of the die cutter is set to be equal to or slightly greater than an inner peripheral shape of the shearing recess 5a of the anvil roll. Specifically, as shown in FIG. 4, it is preferable to satisfy the following relationship: $B \leq A \leq 1.1B$, where $A$ is a length of one of four sides of the outer peripheral shape of the convex push-cutting blade 4a, and $B$ is a length of a corresponding one of four sides of the inner peripheral shape of the shearing recess 5a. The reason is that, if $A$ is less than $B$, burrs are likely to occur in a sheared portion, which causes deterioration in quality of a sheared surface. On the other hand, if $A$ is greater than $1.1B$, a pressing portion, i.e., an area pressing the workpiece plate, becomes excessively widened, which causes deterioration in quality of the workpiece plate.

A shape of the convex push-cutting blade 4a of the die cutter for use in the present invention will be described below. In shearing using the die cutter, as shown in FIGS. 7(a) and 7(b), the convex push-cutting blade 4a of the die cutter is typically formed such that only an outer peripheral portion thereof protrudes outwardly to have an acute distal end. In the present invention, the convex push-cutting blade 4a is not necessarily formed in a protruding shape with an acute distal end as shown in FIGS. 7(a) and 7(b), because it is based on shearing. Thus, the convex push-cutting blade 4a may be formed to protrude in its entirety to have a right-angled edge as shown in FIGS. 7(c) and 7(d), or may be formed to protrude in its entirety to have an obtuse-angled edge s shown in FIGS. 7(e) and 7(f). Further, the edge may be rounded as indi-
[SIXTH EMBODIMENT]

[0063] FIG. 8 illustrates a shearing method according to a sixth embodiment of the present invention. The sixth embodiment is one example where a workpiece plate is sheared using a press roll and an anvil roll. A workpiece plate 1 in the sixth embodiment is the same as that in the first embodiment.

[0064] As shown in FIG. 8, a press roll 9 has a smooth surface devoid of the convex push-cutting blade. An anvil roll 5 disposed opposed to the press roll 9 has a shearing recess 5a provided in a surface thereof in conformity to a shape of a product to be cut off. In the sixth embodiment, the workpiece plate 1 is inserted between the press roll 9 and the anvil roll 5 which are rotating in respective directions, and an intermediate plate 6 having at least one non-metal layer is inserted between the press roll 9 and the workpiece plate 1.

[0065] Then, the press roll 9 is rotated so as to press the workpiece plate 1 toward the shearing recess 5a of the anvil roll to shear the workpiece plate 1. During the shearing operation, the workpiece plate 1 is sheared without pressing the workpiece plate 1 into the shearing recess 5a of the anvil roll. Specifically, the workpiece plate 1 is pressed to a position corresponding to a depth in the shearing recess 5a of the anvil roll which is equal to or greater than a thickness of a metal layer 1a and equal to or less than a total thickness of one or more non-metal layers 1b of the workpiece plate 1. In a test, the workpiece plate 1 was actually pressed into the shearing recess 5a of the anvil roll by a depth of 20 μm. As a result, it was verified that the workpiece plate 1 is fully sheared.

[0066] Although not illustrated, another test was carried out under the following conditions: A workpiece plate stack formed by stacking two workpiece plates 1 on each other is inserted between the press roll 9 and the anvil roll 5, and pressed into the shearing recess 5a of the anvil roll by a depth of 80 μm. As a result, it was verified that both of the two workpiece plates 1 are fully sheared.

[0067] FIG. 9 illustrates one modification of the sixth embodiment in FIG. 8. In the modified embodiment illustrated in FIG. 9, a thin plate made of a metal is sheared as a workpiece plate 7. Specifically, the press roll 9 is rotated so as to press the workpiece plate 7 into the shearing recess 5a of the anvil roll through an intermediate plate 6 to shear the workpiece plate 7.

[0068] More specifically, the workpiece plate is comprised of an aluminum foil having a thickness of 20 μm, and the intermediate plate 6 is comprised of a PET resin having a thickness of 500 μm. Further, a distance (gap) between the press roll 9 and the anvil roll 5 is set to 500 μm. In a test carried out under the above conditions, it was verified that the workpiece plate 7 is fully sheared.

[SEVENTH EMBODIMENT]

[0069] FIG. 10 illustrates a shearing method according to a seventh embodiment of the present invention. In the embodiments illustrated in FIGS. 5, 6, 8 and 9, the intermediate plate 6 to be inserted between the workpiece plate 1 (7) and the die cutter 4 or press roll 9 is formed as a disposable type. Differently, an intermediate plate 6 in the seventh embodiment is formed as a repeatedly usable type.

[0070] Specifically, as shown in FIG. 10, the intermediate plate 6 is formed in an endless configuration. The intermediate plate 6 is inserted between a die cutter 4 and a workpiece plate 1 (7) so as to be used for shearing and then passed between a pair of rolls 10, 10, whereafter the intermediate plate 6 is re-inserted between the die cutter 4 and the workpiece plate 1 (7). Thus, even if plastic deformation corresponding to a shearing recess 5a of the anvil roll (a convex push-cutting blade 4a of the die cutter) occurs in the intermediate plate 6 used for the shearing, due to the pressing during the shearing, the intermediate plate 6 is subsequently passed and pressed between the rolls 10, 10 and returned to a shape approximately identical to its original shape, so that it can be repeatedly used, which is also advantageous in terms of cost.

[0071] In cases where the intermediate plate is repeatedly used, it is preferable that a flexible material such a rubber is used as a material for the intermediate plate 6 to allow the intermediate plate 6 to be easily returned to the original shape. Although the seventh embodiment in FIG. 10 shows one example using the die cutter 4, it is understood that a press roll may be used instead of the die cutter 4.

[EIGHTH EMBODIMENT]

[0072] FIG. 11 illustrates a shearing method according to an eighth embodiment of the present invention. The eighth embodiment is one example where a surface of a press roll 9 is coated with an outer layer 9a including at least one non-metal layer, instead of inserting an intermediate layer between the press roll 9 and a workpiece plate 1 (7).

[0073] The shearing method according to the eighth embodiment is capable of performing shearing in the same manner as that in the shearing method designed to insert the intermediate plate between the press roll 9 and the workpiece plate 1 (7), and avoiding using the intermediate plate in a throwaway manner. During shearing, the workpiece plate 1 (7) is sheared without pressing the workpiece plate 1(7) into a shearing recess 5a of an anvil roll beyond a thickness of the workpiece plate 1(7). Preferably, the outer layer 9a is made of a flexible material such as rubber to allow the outer layer 9a to be easily returned to its original shape.
[NINTH EMBODIMENT]

**[0074]** FIG. 12 illustrates a shearing method according to a ninth embodiment of the present invention. In the ninth embodiment, at least two cutouts 5b are provided at respective positions before and after a shearing recess 5a of an anvil roll 5 in a rotation direction thereof, with a given distance from the shearing recess 5a.

**[0075]** Based on providing the cutout 5b in this manner, it becomes possible to prevent a workpiece plate 1 (7) from being pressed between a die cutter 4 and a portion of an anvil roll 5 unnecessary for shearing of a workpiece plate 1 (7). In other words, an outer peripheral portion of the anvil roll 5 having a length L between a shearing recess 5a of the anvil roll and each of the cutouts 5a is a region required for the shearing of the workpiece plate 1 (7). Thus, the cutouts 5b are provided while leaving the regions, so that it becomes possible to prevent the workpiece plate 1(7) from being pressed between the die cutter 4 and the portion of the anvil roll 5 unnecessary for the shearing, while allowing for the shearing of the workpiece plate 1 (7). This makes it possible to prevent the workpiece plate 1(7) from being damaged due to unnecessary pressing. Particularly, in a workpiece plate having an active material layer (non-metal layer) on a surface thereof as used in the first embodiment, the active material layer is brittle and damageable. Thus, the ninth embodiment is effective in such a workpiece plate.

**[0076]** Depending on a diameter of the anvil roll, it is desirable to set the length L in the range of 0.5 to 2 mm. If the length L is less than 0.5 mm, the anvil roll is likely to damage a surface region of the workpiece plate around a sheared surface. If the length L is greater than 2 mm, a pressing portion, i.e., an area pressing the workpiece plate, becomes excessively widened, which accelerates damage of the workpiece plate. Thus, it is most preferable to set the length L in the range of 0.5 to 2 mm, in view of preventing damage of a surface of the workpiece plate and minimizing the pressing portion. Although the ninth embodiment in FIG. 12 shows one example using the die cutter 4, it is understood that a press roll may be used instead of the die cutter 4.

**[0077]** In cases where an anvil roll is used in the above embodiments, it is preferable that a peripheral edge region of a shearing recess of the anvil roll is made of a material having hardness greater than that of the remaining region of the anvil roll. For example, the peripheral edge region of the shearing recess may be made of hard metal, ceramics or DCL coating. This makes it possible to prevent chipping or the like in the peripheral edge portion of the shearing recess which is a shearing area.

**[0078]** Further, preferably, each of the die cutter, the press roll and a body of the anvil roll is made of a material having a capability to facilitate ensuring machining accuracy, and a Young’s modulus of 150 GPa or more.

### EXPLANATION OF CODES

1. **workpiece plate (thin plate including non-metal layer)**
2. **metal layer**
3. **non-metal layer**
4. **die**
5. **shearing hole**
6. **die cutter**
7. **convex push-cutting blade**
8. **anvil roll**
9. **cutout**
10. **shooting recess**
11. **intermediate plate**
12. **workpiece plate (thin plate made of metal)**
13. **press roll**
14. **outer layer**
15. **roll**

### Claims

1. A method of shearing a thin plate prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, comprising: placing the thin plate between a punch and a die having a shearing hole; and relatively moving the punch toward and with respect to the shearing hole to thereby shear the thin plate, wherein the relative movement of the punch is stopped to complete the shearing, before the punch penetrates through the thin plate and becomes fitted into the shearing hole.

2. The method as defined in claim 1, wherein the metal layer of the thin plate has a thickness less than a total thickness of the one or more non-metal layers of the thin plate, and wherein the relative movement of the punch is stopped at a position corresponding to a depth in the thin plate which is equal to or greater than the thickness of the metal layer and equal to or less than the total thickness of the one or more non-metal layers.

3. The method as defined in claim 1, wherein a plurality of the thin plates are stacked on each other to form a thin plate stack and placed between the punch and the die, and wherein the relative movement of the punch is stopped to complete the shearing, before the punch penetrates through the thin plate stack and becomes fitted into the shearing hole.

4. The method as defined in claim 3, wherein the metal layer of the thin plate has a thickness less than a
<table>
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<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A method of shearing a thin plate made of a metal, comprising: placing the thin plate between a punch and a die having a shearing hole; and relatively moving the punch toward and with respect to the shearing hole to thereby shear the thin plate, wherein an intermediate plate having at least one non-metal layer is placed between the thin plate and the punch, and the relative movement of the punch is stopped to complete the shearing, before the punch penetrates through the intermediate plate.</td>
</tr>
<tr>
<td>2.</td>
<td>The method as defined in claim 1, wherein the metal layer of the thin plate has a thickness less than a total thickness of the one or more non-metal layers of the thin plate stack and equal to or less than a total thickness of the non-metal layers of the thin plate stack.</td>
</tr>
<tr>
<td>3.</td>
<td>A method of shearing a thin plate prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, comprising: inserting the thin plate between a die cutter provided with a convex push-cutting blade on a surface thereof, and an anvil roll provided with a shearing recess at a position corresponding to the convex push-cutting blade; and rotating and pressing the convex push-cutting blade of the die cutter toward the shearing recess of the anvil roll to thereby shear the thin plate, wherein the thin plate is sheared without causing the convex push-cutting blade of the die cutter to penetrate through the thin plate stack and become fitted into the shearing recess of the anvil roll.</td>
</tr>
<tr>
<td>4.</td>
<td>The method as defined in claim 7, wherein the metal layer of the thin plate has a thickness less than a total thickness of the one or more non-metal layers of the thin plate, and wherein the convex push-cutting blade of the die cutter is thrust to a position corresponding to a depth in the thin plate stack which is equal to or greater than a total thickness of the metal layers of the thin plate stack and equal to or less than a total thickness of the non-metal layers of the thin plate stack.</td>
</tr>
<tr>
<td>5.</td>
<td>A method of shearing a thin plate prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, comprising: inserting the thin plate between a die cutter and the thin plate or thin plate stack.</td>
</tr>
<tr>
<td>6.</td>
<td>The method as defined in claim 5, wherein the thin plate has a thickness less than that of the intermediate plate, and wherein the relative movement of the punch is stopped at a position corresponding to a depth in a combination of the thin plate and the intermediate plate which is equal to or greater than the thickness of the thin plate and equal to or less than the thickness of the intermediate plate.</td>
</tr>
<tr>
<td>7.</td>
<td>A method of shearing a thin plate prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, comprising: inserting the thin plate between a die cutter provided with a convex push-cutting blade on a surface thereof, and an anvil roll provided with a shearing recess at a position corresponding to the convex push-cutting blade; and rotating and pressing the convex push-cutting blade of the die cutter toward the shearing recess of the anvil roll to thereby shear the thin plate, wherein the thin plate is sheared without causing the convex push-cutting blade of the die cutter to penetrate through the thin plate and become fitted into the shearing recess of the anvil roll.</td>
</tr>
<tr>
<td>8.</td>
<td>The method as defined in claim 7, wherein the metal layer of the thin plate has a thickness less than a total thickness of the one or more non-metal layers of the thin plate, and wherein the convex push-cutting blade of the die cutter is thrust to a position corresponding to a depth in the thin plate which is equal to or greater than the thickness of the metal layer and equal to or less than the total thickness of the one or more non-metal layers.</td>
</tr>
<tr>
<td>9.</td>
<td>The method as defined in claim 7, wherein a plurality of the thin plates are stacked on each other to form a thin plate stack and inserted between the die cutter and the anvil roll, wherein all of the thin plates are sheared without causing the convex push-cutting blade of the die cutter to penetrate through the thin plate stack and become fitted into the shearing recess of the anvil roll.</td>
</tr>
<tr>
<td>10.</td>
<td>The method as defined in claim 9, wherein the metal layer of the thin plate has a thickness less than a total thickness of the one or more non-metal layers of the thin plate, and wherein the convex push-cutting blade of the die cutter is thrust to a position corresponding to a depth in the thin plate stack which is equal to or greater than a total thickness of the metal layers of the thin plate stack and equal to or less than a total thickness of the non-metal layers of the thin plate stack.</td>
</tr>
<tr>
<td>11.</td>
<td>The method as defined in claim 7 or 9, wherein an intermediate plate having at least one non-metal layer is inserted between the die cutter and the thin plate or thin plate stack.</td>
</tr>
<tr>
<td>12.</td>
<td>The method as defined in claim 11, wherein the metal layer of the thin plate has a thickness less than a total thickness of the one or more non-metal layers of the thin plate and a thickness of the intermediate plate, and wherein the convex push-cutting blade of the die cutter is thrust to a position corresponding to a depth in a combination of the intermediate plate and the thin plate or thin plate stack which is equal to or greater than a total thickness of the metal layers of the thin plate or thin plate stack and equal to or less than a total thickness of the non-metal layers of the thin plate or thin plate stack and the intermediate plate.</td>
</tr>
<tr>
<td>13.</td>
<td>The method as defined in claim 11 or 12, wherein the intermediate plate is formed in an endless configuration, and wherein the intermediate plate is inserted between the die cutter and the thin plate or thin plate stack and then passed and pressed between a pair of rolls, whereafter the intermediate plate is re-inserted between the die cutter and the thin plate or thin plate stack.</td>
</tr>
<tr>
<td>14.</td>
<td>The method as defined in any one of claims 7 to 13, wherein the shearing recess of the anvil roll has a peripheral edge region made of a material having hardness greater than that of the remaining region of the anvil roll.</td>
</tr>
<tr>
<td>15.</td>
<td>The method as defined in any one of claims 7 to 14, wherein the anvil roll has at least two cutouts provided at respective positions before and after the shearing recess in a rotation direction thereof, with a given distance from the shearing recess.</td>
</tr>
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</table>
| 16.  | A method of shearing a thin plate made of a metal, comprising: inserting the thin plate between a die
A method of shearing a thin plate which is made of a metal or prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, comprising: inserting the thin plate between a press roll and an anvil roll provided with a shearing recess; and rotating the press roll to press the thin plate toward the shearing recess of the anvil roll to thereby shear the thin plate, wherein an intermediate plate having at least one non-metal layer is inserted between the thin plate and the die cutter, and the thin plate is sheared without causing the convex push-cutting blade of the die cutter to penetrate through the intermediate plate and become fitted into the shearing recess of the anvil roll.

17. The method as defined in claim 16, wherein the thin plate has a thickness less than that of the intermediate plate, and wherein the convex push-cutting blade of the die cutter is thrust to a position corresponding to a depth in a combination of the thin plate and the intermediate plate which is equal to or greater than the thickness of the thin plate and equal to or less than the thickness of the intermediate plate.

18. The method as defined in claim 16 or 17, wherein the intermediate plate is formed in an endless configuration, and wherein the intermediate plate is inserted between the die cutter and the thin plate and then passed and pressed between the die cutter and the anvil roll, whereafter the intermediate plate is reinserted between the die cutter and the thin plate.

19. The method as defined in any one of claims 16 to 18, wherein the shearing recess of the anvil roll has a peripheral edge region made of a material having hardness greater than that of the remaining region of the anvil roll.

20. The method as defined in any one of claims 16 to 19, wherein the anvil roll has at least two cutouts provided at respective positions before and after the shearing recess in a rotation direction thereof, with a given distance from the shearing recess.

21. A method of shearing a thin plate which is made of a metal or prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, comprising: inserting the thin plate between a press roll, and an anvil roll provided with a shearing recess; and rotating the press roll to press the thin plate toward the shearing recess of the anvil roll to thereby shear the thin plate, wherein an intermediate plate having at least one non-metal layer is inserted between the thin plate and the die cutter, and the thin plate is sheared without pressing the thin plate into the shearing recess of the anvil roll beyond a thickness of the thin plate.

22. The method as defined in claim 21, wherein the thin plate is prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, and wherein the thin plate is pressed to a position corresponding to a depth in the shearing recess of the anvil roll which is equal to or greater than a thickness of the metal layer and equal to or less than a total thickness of the one or more non-metal layers of the thin plate.

23. The method as defined in claim 21, wherein the thin plate is prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, and wherein a plurality of the thin plates are stacked on each other to form a thin plate stack, and wherein the intermediate plate having at least one non-metal layer is inserted between the thin plate stack and the press roll, and the thin plate stack is sheared without pressing the thin plate stack into the shearing recess of the anvil roll beyond a thickness of the thin plate stack.

24. The method as defined in claim 23, wherein the thin plate stack is pressed to a position corresponding to a depth in the shearing recess of the anvil roll which is equal to or greater than a total thickness of the metal layers of the thin plate stack and equal to or less than a total thickness of the non-metal layers of the thin plate stack.

25. The method as defined in any one of claims 21 to 24, wherein the intermediate plate is formed in an endless configuration, and wherein the intermediate plate is inserted between the press roll and the thin plate or thin plate stack and then passed and pressed between a pair of rolls, whereafter the intermediate plate is reinserted between the press roll and the thin plate or thin plate stack.

26. The method as defined in any one of claims 21 to 25, wherein the shearing recess of the anvil roll has a peripheral edge region made of a material having hardness greater than that of the remaining region of the anvil roll.

27. The method as defined in any one of claims 21 to 26, wherein the anvil roll has at least two cutouts provided at respective positions before and after the shearing recess in a rotation direction thereof, with a given distance from the shearing recess.

28. A method of shearing a thin plate which is made of a metal or prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, comprising: inserting the thin plate between a press roll having a surface coated with a layer including at least one non-metal layer, and an anvil roll provided with a shearing recess; and rotating the press roll to press the thin plate to-
ward the shearing recess of the anvil roll to thereby shear the thin plate, wherein the thin plate is sheared without pressing the thin plate into the shearing recess of the anvil roll beyond a thickness of the thin plate.

29. The method as defined in claim 28, wherein the thin plate is prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, and wherein the thin plate is pressed to a position corresponding to a depth in the shearing recess of the anvil roll which is equal to or greater than a thickness of the metal layer and equal to or less than a total thickness of the one or more non-metal layers of the thin plate.

30. The method as defined in claim 28, wherein the thin plate is prepared by laminating one or more non-metal layers on one or respective ones of opposite surfaces of a metal layer, and wherein a plurality of the thin plates are stacked on each other to form a thin plate stack, and wherein the thin plate stack is inserted between the press roll and the anvil roll, and sheared without pressing the thin plate stack into the shearing recess of the anvil roll beyond a thickness of the thin plate stack.

31. The method as defined in claim 30, wherein the thin plate stack is pressed to a position corresponding to a depth in the shearing recess of the anvil roll which is equal to or greater than a total thickness of the metal layers of the thin plate stack and equal to or less than a total thickness of the non-metal layers of the thin plate stack.

32. The method as defined in any one of claims 28 to 31, wherein the shearing recess of the anvil roll has a peripheral edge region made of a material having hardness greater than that of the remaining region of the anvil roll.

33. The method as defined in any one of claims 28 to 32, wherein the anvil roll has at least two cutouts provided at respective positions before and after the shearing recess in a rotation direction thereof, with a given distance from the shearing recess.
Fig. 7

(a)

(b)

(c)

(d)

(e)

(f)
## INTERNATIONAL SEARCH REPORT

### A. CLASSIFICATION OF SUBJECT MATTER

B21D28/02 (2006.01.1), B21D28/12 (2006.01.1)

According to International Patent Classification (IPC) or to both national classification and IPC

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B21D28/02, B21D28/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

- Jitsuyo Shinan Koho 1922-1996
- Jitsuyo Shinan Tozoku Koho 1996-2009
- Kokai Jitsuyo Shinan Koho 1971-2009
- Toroku Jitsuyo Shinan Koho 1994-2009

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>X</td>
<td>JP 2000-218598 A (Hitachi Cable, Ltd.), 08 August 2000 (08.08.2000), claim 1; fig. 1 to 3 (Family: none)</td>
<td>5, 6</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>1-4, 7-33</td>
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<td>X</td>
<td>JP 2001-293694 A (Hitachi Cable, Ltd.), 23 October 2001 (23.10.2001), claim 1; paragraph [0024]; fig. 1 to 4 (Family: none)</td>
<td>21, 25, 26, 28, 32</td>
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</table>

- **X** Further documents are listed in the continuation of Box C.
- **A** See patent family annex.

- **+** Special category of cited documents:
  - "A" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier application or patent published on or after the international filing date
  - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  - "O" document referring to an oral disclosure, use, exhibition or other means
  - "P" document published prior to the international filing date but later than the priority date claimed

- **I** Later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

- **X** Document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

- **Y** Document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

- **&** Document member of the same patent family

**Date of the actual completion of the international search:**

06 October, 2009 (06.10.09)

**Date of mailing of the international search report:**

20 October, 2009 (20.10.09)

**Name and mailing address of the ISA/ 日本特許庁**

**Authorized officer**

**Telephone No.**
## DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>A</td>
<td>JP 2002-216775 A (Showa Precision Tools Co., Ltd.), 02 August 2002 (02.08.2002), entire text (Family: none)</td>
<td>1-33</td>
</tr>
</tbody>
</table>

Form PCT/ISA/210 (continuation of second sheet) (April 2007)
INTERNAL SEARCH REPORT

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The matter common to the inventions of claims 1 – 33 is "to shear a metallic sheet through a nonmetal layer". However, the search has revealed that the aforementioned common matter is not novel, since it was disclosed in Document 1: JP 2000-218598 (Hitachi Cable, Ltd.), 08 August 2000 (08 August 2000), claim 1, fig. 1 - 3. As a result, the aforementioned common matter is not the special technical feature within the meaning of PCT Rule 13.2, second sentence, since the common matter makes no contribution over the prior art. Therefore, there exists no matter common to all the inventions of claims 1 – 33. No technical relationship within the meaning of PCT Rule 13 can be seen between those different inventions, (continued to extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:  

Remark on Protest the  ☐ The additional search fees were accompanied by the applicant’s protest and, where applicable, payment of a protest fee.

☐ The additional search fees were accompanied by the applicant’s protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2007)
since there exists no other common matter which can be considered as a special technical feature within the meaning of PCT Rule 13.2, second sentence. Hence, it is apparent that the inventions of claims 1 - 33 do not comply with the requirement of unity of invention.
REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description


Non-patent literature cited in the description