

DESCRIPTION

CUTTING METHOD

5 TECHNICAL FIELD

[0001]

The present invention relates to a cutting method for cutting a workpiece.

BACKGROUND ART

10 [0002]

Various kinds of surface-treated materials are produced according to the applications, such as a plated metal sheet for which the surface of a metallic material has been subjected to a plating treatment, or a painted metal sheet for which the surface of a metallic material has been painted. For example, plated steel sheets which are
15 excellent in corrosion resistance are utilized for building materials, automobiles, and household electrical appliances.

[0003]

Components which use a surface-treated material that was produced by subjecting a workpiece to a surface treatment are manufactured, for example, by
20 cutting the workpiece that was subjected to the surface treatment, and thereafter processing the cut workpiece. Cutting of a workpiece 5 can be performed, for example, by cutting the workpiece 5 using a shearing tool 10 as illustrated in Figure 13. The shearing tool 10 is composed of a die 11, a punch 12 and a blank holder 13. For example, in a state in which one end of the workpiece 5 is restrained by the die 11 and
25 the blank holder 13, the punch 12 which has been placed to have a clearance d with respect to the die 11 is moved relatively to the die 11 side to apply a shearing force to the workpiece 5. By this means, the workpiece 5 is cut.

[0004]

The workpiece 5 which was subjected to a surface treatment that was cut
30 using the shearing tool 10 illustrated in Figure 13 has a cut end face as illustrated in

Figure 14. The cut end face of the workpiece 5 is composed of a shear drop, a shear surface, and a fracture surface. The shear drop is a deformation caused by a tensile force acting on the top surface of the workpiece 5 when, with respect to the workpiece 5 in which the surface of a metallic material 5a as the base material has been covered with a coating layer 5b, the punch 12 illustrated in Figure 13 is pushed down from the top surface side toward the bottom surface side of the workpiece 5. The shear surface is a smooth surface formed by movement of the punch 12 which sunk into the workpiece 5, and the fracture surface is a surface at which cracks that arose in the workpiece 5 served as rupture starting points and the workpiece 5 ruptured. As illustrated in Figure 14, at the cut end face of the workpiece 5, although the coating layer 5b remains at the shear drop portion, almost none of the coating layer 5b remains at the shear surface, and the metallic material 5a is exposed at the fracture surface.

[0005]

In this regard, at the cut end face of the workpiece 5, the corrosion resistance of the shear surface and the fracture surface at which the metallic material 5a is almost fully exposed is low, and there is a concern that red rust may occur. For example, sacrificial protection by a plated metal layer or chemical treatment are commonly employed as measures for preventing rust at the cut end face of a plated metal sheet in which a plated metal layer is formed on the surface of a metallic material. For example, Patent Document 1 discloses that a cutting process is performed so that, within a range of 0.10 times or more of the sheet thickness in the sheet thickness direction, the size of a shear drop of a cut end face falls within a range of 0.45 times or more of the sheet thickness in the flat surface direction. A tensile force and a shearing force applied to the metallic material are increased by such a cutting process, a plated metal layer coated on the surface of the base metal material is caused to go around to the cut end face, and at least one part of the shear surface of the cut end face is covered with the plated metal layer. The occurrence of red rust at the cut end face is suppressed by a sacrificial protection action of the plated metal layer that went around to the cut end face.

[0006]

Further, Patent Document 2 discloses a method in which a surface-treated steel sheet is cut with a rotary blade that is shifted upward and downward, and thereafter the end face is subjected to a processing using a forming roll.

[0007]

5 Further, Patent Document 3 discloses a cutting method in which V-shaped grooves are formed on a steel sheet including a plating layer in a first process, and strain is applied to the steel sheet along the formed grooves to cut the steel sheet in a second process.

[0008]

10 Furthermore, Patent Document 4 discloses an apparatus including three sets of rotary blades that have cutting edges with various heights and widths and are arranged in tandem, and the apparatus shears a strip-shaped material gradually.

LIST OF PRIOR ART DOCUMENTS

15 PATENT DOCUMENT

[0009]

Patent Document 1: JP2017-87294A

Patent Document 2: JP2018-075600A

Patent Document 3: JP2004-34183A

20 Patent Document 4: JPS61-125718A

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0010]

25 However, in the aforementioned Patent Document 1, the plated metal layer on the surface of the base metal material only covers at least one part of the shear surface of the cut end face, and the base metal material remains exposed at the fracture surface. Consequently, the corrosion resistance of the cut end face of the plated metal sheet is not sufficient. Further, in general, when it is attempted to impart an excessive
30 sacrificial protection property to the cut end face for the purpose of rust prevention, the

plating on the surface of the plated metal sheet decreases, and the surface corrosion resistance at the surface of the plated metal sheet (that is, the flat surface corrosion resistance) decreases.

[0011]

5 Further, in the aforementioned Patent Document 2, the plating coverage is increased by performing two processes, namely, a process for cutting a surface-treated steel sheet, and a process for forming an end face portion of the surface-treated steel sheet that was cut. However, because it is necessary to perform a plurality of processes, the equipment cost increases. Further, in the technique described in Patent
10 Document 2, after cutting the surface-treated steel sheet with a rotary blade that is shifted upward and downward, the shape of the end face portion is adjusted, and consequently, because stress is imparted in different directions in the respective processes, cracking or peeling is liable to occur in the plating layer. In addition, in the technique described in Patent Document 2, it is necessary to cause a greater amount
15 of the plating layer to flow from the surface side in order to cover the end face of the steel sheet which is the base material. Consequently, there is a possibility that a defect such as cracking of the plating at the outer layer or localized thinning of the plating may occur, or the plating may flow onto the surface of the steel sheet to which an oxide coating or contamination has adhered, resulting in poor adhesion of the
20 plating.

[0012]

Further, in the aforementioned Patent Document 3, stress applied to the steel sheet in the first process for forming the groove on the steel sheet is different from stress applied to the steel sheet in the second process for cutting the steel sheet, and
25 therefore the ability of the plating layer to follow the movement of blades is not high. When the second process is performed in a state in which no damage that contributes to sufficient ductile fracture occurs in the steel sheet in the first process, cracks propagate to gouge out inclined faces of the V-shaped grooves. As a result, a fracture surface and a shear surface generated by the cutting in the second process are not
30 covered with plating, and a plating coverage decreases. The thicker a sheet thickness

of the steel sheet is, the more this tendency becomes prominent. In the cutting method described in Patent Document 3, it is difficult to cut a steel sheet having a thin sheet thickness.

[0013]

5 Further, the aforementioned Patent Document 4 proposes a cutting apparatus with which Patent Document 4 has an objective to obtain a small strip-shaped body with beautiful, proper side edges by cutting a steel sheet without causing burrs, shear drops, peeling of swarf, and the like on a cut surface. However, Patent Document 4 pays no attention to the durability of cutting edges of the annular blades. Furthermore,
10 for achieving the objective of Patent Document 4, Patent Document 4 has no study about the optimization of cross-sectional front end radii of cutting edges of the cutting apparatus.

[0014]

Therefore, the present invention has been made in view of the problems
15 described above, and an objective of the present invention is to provide a novel and improved cutting method which, with respect to cutting of a workpiece, are capable of suppressing the occurrence of a situation in which the performance which the workpiece has is reduced after the cutting.

20 SOLUTION TO PROBLEM

[0015]

According to an embodiment of the present invention, there is provided a cutting method for cutting a workpiece using a cutting apparatus, wherein the cutting apparatus includes at least one pair of cutting parts including a first annular cutting part
25 and a second annular cutting part, a first cutting edge provided on an outer edge of the first annular cutting part and a second cutting edge provided on an outer edge of the second annular cutting part each have a V-shaped radial-direction profile, a front end angle θ_1 of the first cutting edge and a front end angle θ_2 of the second cutting edge being 10° or more and 120° or less, a front end radius R_1 of the first cutting edge and a
30 front end radius R_2 of the second cutting edge being 0.5% or more and 35.0% or less of

a sheet thickness, and the workpiece is cut by causing the workpiece to pass between the first cutting edge and the second cutting edge facing each other and pushing the cutting edges into the workpiece.

[0016]

- 5 The workpiece may be a multi-layer material formed by coating a surface of a base material with a coating material.

[0017]

The cutting of the workpiece may be carried out by performing a plurality of cutting processes.

- 10 [0018]

In cutting of the workpiece by performing the plurality of cutting processes, the front end angle θ_1 of the first cutting edge and the front end angle θ_2 of the second cutting edge may be made smaller gradually through the cutting processes.

[0019]

- 15 In a case where the workpiece is cut by performing two cutting processes, when a front end radius of the first cutting edge is defined as R_1 , a front end radius of the second cutting edge is defined as R_2 , and a sheet thickness of the workpiece is defined as t , a space S between the first cutting edge and the second cutting edge in a first cutting process may satisfy expression (1) below.

- 20 $(R_1 + R_2) \leq S \leq \{t - (R_1 + R_2)\}$...(1)

[0020]

- A trimming width of the workpiece is a distance between one of end portions of the workpiece and a cutting position of the workpiece, and when a front end radius of the first annular cutting part is defined as R_1 , a front end radius of the second annular cutting part is defined as R_2 , and a sheet thickness of the workpiece is defined as t , a trimming width D of the workpiece may satisfy expression (2) below.

$$R \leq D \leq 3t \quad \dots(2)$$

$$R = \text{Min}(R_1, R_2)$$

[0021]

- 30 An amount of offset L_D between annular cutting parts in a strip running

direction is 1 mm or more, and the workpiece may be cut at only one place in a single cutting process.

[0022]

5 In a case where the number of the at least one pair of cutting parts provided in the cutting apparatus is more than one, a distance W between the cutting parts adjacent to each other in a sheet width direction may be 200 mm or more.

[0023]

A diameter of each of the first annular cutting part and the second annular cutting part may be 50 mm or more.

10

ADVANTAGEOUS EFFECTS OF INVENTION

[0024]

As described above, according to the present invention, when cutting a workpiece, the occurrence of a situation in which the performance which the workpiece has is reduced after cutting can be suppressed. For example, when cutting a workpiece which was subjected to a surface treatment, while maintaining the function of a coating material on a flat surface of the base material, the function of the coating material can also be caused to be realized on a cut end face.

20 BRIEF DESCRIPTION OF DRAWINGS

[0025]

[Figure 1] Figure 1 is an explanatory drawing illustrating one example of a cutting apparatus according to an embodiment of the present invention.

25 [Figure 2] Figure 2 is a cross-sectional view of the cutting apparatus illustrated in Figure 1 taken along the cutting line I-I.

[Figure 3] Figure 3 is a partially enlarged view of an upper rotary part and lower rotary part of the cutting apparatus according to the embodiment.

[Figure 4] Figure 4 is an explanatory drawing illustrating another example of a cutting apparatus according to the embodiment.

30 [Figure 5] Figure 5 is an explanatory drawing illustrating how to adjust the positions of

annular cutting parts of the cutting apparatus illustrated in Figure 4.

[Figure 6] Figure 6 is an explanatory drawing illustrating one example of a twin-edged roll.

[Figure 7] Figure 7 is an explanatory drawing illustrating schematically a cut end face of a workpiece cut by the cutting apparatus according to the embodiment.

[Figure 8] Figure 8 is a graph illustrating an example of the relation between trimming widths and fracture surface ratios.

[Figure 9] Figure 9 is a schematic diagram illustrating two roll parts of an upper rotary part of the cutting apparatus illustrated in Figure 4 when seen in plan view.

[Figure 10] Figure 10 shows, as Example, front photographs of cut end faces of plated metallic materials which were cut with a cutting apparatus.

[Figure 11] Figure 11 shows, as Example, lateral cross-sectional photographs of cut end faces of plated metallic materials which were cut with a cutting apparatus.

[Figure 12] Figure 12 illustrates an enlarged image of the cut end face of the workpiece in Example 3.

[Figure 13] Figure 13 is an explanatory drawing illustrating one example of a conventional shearing tool.

[Figure 14] Figure 14 is an explanatory drawing that schematically illustrates a cut end face of a workpiece which was cut using the shearing tool illustrated in Figure 13.

DESCRIPTION OF EMBODIMENTS

[0026]

Hereunder, preferred embodiments of the present invention are described in detail while referring to the accompanying drawings. Note that, in the present specification and the accompanying drawings, constituent elements having substantially the same functional configuration are denoted by the same reference characters and a duplicate description thereof is omitted.

[0027]

<1. Cutting apparatus>

First, based on Figure 1 to Figure 3, a schematic configuration of a cutting

apparatus 100 according to one embodiment of the present invention will be described. Note that, Figure 1 is an explanatory drawing illustrating one example of the cutting apparatus 100 according to the present embodiment. Figure 2 is a cross-sectional view of the cutting apparatus 100 illustrated in Figure 1 taken along the cutting line I-I.

5 Figure 3 is a partially enlarged view of an upper rotary part 110 and lower rotary part 120 of the cutting apparatus 100 according to the present embodiment. Figure 3 illustrates only halves of the upper rotary part 110 and the lower rotary part 120 from rotation centers thereof. In Figure 1 to Figure 3, description will be made with the sheet width direction of the workpiece being taken as the X direction, the sheet length direction being taken as the Y direction, and the sheet thickness direction being taken as the Z direction. The Y direction may be regarded as the strip running direction of the workpiece.

[0028]

The cutting apparatus 100 is an apparatus that cuts a workpiece 5 (see Figure 3 and Figure 7) that has been subjected to a surface treatment with a pair of rotating cutting parts. In the following description, a surface-treated material having covering layers (coating layers 5b in Figure 7) on the surfaces of a metallic material (a metallic material 5a in Figure 7) that is a base material is adopted as an example of the workpiece 5. Examples of this kind of the workpiece 5 include a plated metal sheet obtained by subjecting the surfaces of a metal sheet to a plating treatment, a painted metal sheet obtained by coating the surfaces of a metallic material as a base material with paint, and a film-laminated metal sheet obtained by laminating a film on a metal sheet.

[0029]

25 The cutting apparatus 100 can include a plurality of pairs of cutting parts and may include three pairs of cutting parts 1, 2, and 3 as illustrated in Figure 1. The pairs of cutting parts 1, 2, and 3 include first annular cutting parts 111, 112, and 113, and second annular cutting parts 121, 122, and 123, respectively. The first annular cutting parts and the second annular cutting parts in pairs are arranged such that, as illustrated in Figure 3, front ends 111b, 112b, 113b, 121b, 122b, and 123b of cutting

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edges 111a, 112a, 113a, 121a, 122a, and 123a on outer edges of the first annular cutting parts and the second annular cutting parts face one another. The cutting edges 111a, 112a, 113a, 121a, 122a, and 123a of the first annular cutting parts 111, 112, and 113 and the second annular cutting parts 121, 122, and 123 each have a V-shaped radial-direction profile.

[0030]

The first annular cutting parts 111, 112, and 113 are supported by a first shaft part 115 at rotation centers of the first annular cutting parts 111, 112, and 113. The second annular cutting parts 121, 122, and 123 are supported by a second shaft part 125 at rotation centers of the second annular cutting parts 121, 122, and 123. As illustrated in Figure 2, the first shaft part 115 and the second shaft part 125 are rotatably supported by a pair of supporting parts 103a and 103b at both ends of the first shaft part 115 and the second shaft portion 125 via chocks 105a and 105b and chocks 107a and 107b, respectively (chocks 105a and 107a are not illustrated). The pair of supporting parts 103a and 103b are provided on a base 101 illustrated in Figure 1.

[0031]

Between the supporting parts 103a and 103b, sleeves 131 and 133 may be provided together with the first annular cutting parts 111, 112, and 113 and the second annular cutting parts 121, 122, and 123. The sleeves 131 and 133 are members for adjusting distances between the first annular cutting parts 111, 112, and 113 and distances between the second annular cutting parts 121, 122, and 123. In Figure 1, the sleeves 131 and 133 having different widths are provided; however, only sleeves having the same width may be used to adjust the distances between the first annular cutting parts 111, 112, and 113 and the distances between the second annular cutting parts 121, 122, and 123.

[0032]

Hereinafter, the first annular cutting parts 111, 112, and 113 and the sleeves 131 and 133 supported by the first shaft part 115 will be also referred to as the upper rotary part 110. In addition, the second annular cutting parts 121, 122, and 123 and the sleeves 131 and 133 supported by the second shaft part 125 will be also referred to

as the lower rotary part 120. The upper rotary part 110 rotates integrally with the first shaft part 115. The lower rotary part 120 rotates integrally with the second shaft part 125.

[0033]

5 The pair of supporting parts 103a and 103b are movable in the sheet width direction (the X direction) by driving units 104a and 104b. For example, as illustrated in Figure 1, the pair of supporting parts 103a and 103b are in threaded engagement with thread parts 102a and 102b that are arranged to be parallel to the first shaft part 115 and the second shaft part 125. The thread parts 102a and 102b have
10 one ends connected to the driving units 104a and 104b, respectively. By driving the driving units 104a and 104b to rotate the thread parts 102a and 102b, the supporting parts 103a and 103b are caused to move.

[0034]

By driving the driving units 104a and 104b to move the supporting parts 103a
15 and 103b in the sheet width direction such that the supporting parts 103a and 103b are separated from each other, one ends of the first shaft part 115 and the second shaft part 125 come off from the chocks. This enables the sleeves 131 and 133, the first annular cutting parts 111, 112, and 113, and the second annular cutting parts 121, 122, and 123 to be detached from the first shaft part 115 and the second shaft part 125, which allows
20 changing of the annular cutting parts or the sleeves for adjusting the distances between the annular cutting parts.

[0035]

Atop the supporting parts 103a and 103b, the pressing devices 109a and 109b are provided as space adjusting units that adjust a space between the first annular
25 cutting parts 111, 112, and 113 and the second annular cutting parts 121, 122, and 123. By tightening the pressing devices 109a and 109b, the space between the first annular cutting parts 111, 112, and 113 and the second annular cutting parts 121, 122, and 123 can be narrowed.

[0036]

30 In the cutting apparatus 100 according to the present embodiment, the space

between first annular cutting parts 111, 112, and 113 and second annular cutting parts 121, 122, and 123 is adjusted according to a sheet thickness of the workpiece 5 by pressing devices 109a and 109b. Then, the workpiece 5 is caused to pass between the upper rotary part 110 and the lower rotary part 120 while the upper rotary part 110 and the lower rotary part 120 are rotating, thereby cutting the workpiece 5. When the workpiece 5 passes between the upper rotary part 110 and the lower rotary part 120, coating layers on the surfaces of the workpiece 5 are caused to extend onto a cut end face by means of tensile forces that arise between the workpiece 5 and a pair of cutting parts, for example, the cutting edge of the first annular cutting part 111 (112, 113) and the cutting edge of the second annular cutting part 121 (122, 123), so that the cut end face is covered with the coating layer. That is, the coating layers on the surfaces of the workpiece 5 are caused to follow the movements of the cutting edge 111a (112a, 113a) of the first annular cutting part 111 (112, 113) and the cutting edge 121a (122a, 123a) of the second annular cutting part 121 (122, 123) with respect to the workpiece 5 when the workpiece 5 passes between the upper rotary part 110 and the lower rotary part 120, and the coating layers are caused to extend onto the cut end face. By this means, the cut end face of the workpiece 5 is coated with the coating layer.

[0037]

Note that, the cutting apparatus according to the present embodiment is not limited to the configuration illustrated in Figure 1. For example, as illustrated in Figure 4, a cutting apparatus 100A may have a configuration in which an upper rotary part 110A and a lower rotary part 120A are each divided into two roll parts that are supported by the supporting parts 103a and 103b. One of the roll parts of the upper rotary part 110A is provided with an annular cutting part 111, and the other of the roll parts is provided with an annular cutting part 113. One of the roll parts of the lower rotary part 120A is provided with an annular cutting part 121, and the other of the roll parts is provided with an annular cutting part 123. Also in such a cutting apparatus 100A, coating layers on the surfaces of a workpiece are caused to follow the movements of the annular cutting parts 111, 113, 121, and 123 when the workpiece is cut, and the coating layers are caused to extend onto the cut end face, as with the

cutting apparatus 100 illustrated in Figure 1. By this means, the cut end face of the workpiece is coated with the coating layer.

[0038]

Also in the cutting apparatus 100A illustrated in Figure 4, the positions of the
5 annular cutting parts 111, 113, 121, and 123 can be adjusted, as with the cutting apparatus 100 illustrated in Figure 1. Based on Figure 5, how to adjust the positions of the annular cutting parts of the cutting apparatus 100A will be described. Note that, based on Figure 5, a case where the position of the annular cutting part 113 of the upper rotary part 110A provided around a first shaft part 115b is adjusted will be
10 described, and the annular cutting parts 111, 121, and 123 provided around a first shaft part 115a and second shaft parts 125a and 125b, respectively, are to be adjusted similarly.

[0039]

An installation position of the annular cutting part 113 illustrated in Figure 5
15 on the first shaft part 115b is adjusted with sleeves 131 and 135 of which lengths are different from each other in a shaft direction of the first shaft part 115b (the Y direction). The sleeve 131 is longer than the sleeve 135 in the shaft direction. In the upper part of Figure 5, the sleeve 131, the annular cutting part 113, and the sleeve 135 are provided on the first shaft part 115b in order closest to a supporting part 103b. At
20 a front end of the first shaft part 115b (an end portion on the opposite side to the supporting part 103b), a stopper 137 is fastened, fixing the sleeve 131, the annular cutting part 113, and the sleeve 135 to the first shaft part 115b. The lower part of Figure 5 illustrates the installation position of the annular cutting part 113 in a case where the positions of the sleeve 131 and the sleeve 135 are switched from the state
25 illustrated in the upper part of Figure 5. From Figure 5, by adjusting the installation positions of the sleeves 131 and 135 having different lengths, it is possible to adjust the position of the annular cutting part 113 in the shaft direction.

[0040]

Further, only one annular cutting part may be provided on one roll part as
30 illustrated in Figure 4, or a plurality of annular cutting parts may be provided. A

cutting apparatus in which a plurality of annular cutting parts are provided on one roll part can be configured by, for example, providing a twin-edged roll 1110 including two annular cutting parts 1111 and 1112 provided at both ends in the shaft direction of a shaft part 1113 as illustrated in Figure 6, in place of the annular cutting part 111 illustrated in Figure 4. By using the twin-edged roll 1110, in a case where one of the annular cutting parts used for cutting a workpiece wears, for example, the workpiece can be continuously cut by reversing and reinstalling the twin-edged roll 1110 such that the workpiece is cut by the other of the annular cutting parts. By this means, the number of times the annular cutting parts are polished can be reduced.

[0041]

<2. Covering of cut end face by coating layer>

An example of the cut end face of a workpiece 5 cut by the cutting apparatus 100 is illustrated in Figure 7. In Figure 7, a cross section of a side face (i.e., a face viewed from the sheet length direction (the Y direction)) of the cut end face of the workpiece 5 is schematically illustrated. As illustrated in Figure 7, the cut end face of the workpiece 5 is composed of shear drops s1 and s2, inclined faces s3 and s4, and a fracture surface s5. The shear drop s1 and the inclined face s3 are formed by a first cutting edge of the first annular cutting part of the pair of cutting parts, and the shear drop s2 and the inclined face s4 are formed by a second cutting edge of the second annular cutting part. The fracture surface s5 is formed as a result of workpiece 5 rupturing in a manner in which cracks generated in the workpiece 5 by the first cutting edge and the second cutting edge serve as starting points.

[0042]

As illustrated in Figure 7, the coating layer 5b on the top surface side of the metallic material 5a covers the metallic material 5a continuously from the surface of the metallic material 5a to the shear drop s1 and the inclined face s3. Similarly, the coating layer 5b on the bottom surface side of the metallic material 5a covers the metallic material 5a continuously from the surface of the metallic material 5a to the shear drop s2 and the inclined face s4. Thus, in the workpiece 5 cut by the cutting apparatus 100 according to the present embodiment, the region from each surface of

the metallic material 5a to the cut end face is covered with the same continuous coating layer 5b. For example, after the workpiece 5 is cut, it is possible to cover the cut end face by subjecting the cut end face to a surface treatment such as plating or painting. However, it is difficult to cover the cut end face with a material that has the same composition as the coating layers 5b of the workpiece 5, and the corrosion resistance of the cut end face will be low compared to the surfaces of the metallic material 5a.

[0043]

In contrast, because the workpiece 5 cut by the cutting apparatus 100 according to the present embodiment is covered from each surface to the cut end face of the metallic material 5a with the same continuous coating layer 5b simultaneously with cutting, the cut end face resists being oxidized. Therefore, by cutting the workpiece 5 using the cutting apparatus 100 according to the present embodiment, the workpiece 5 that has high corrosion resistance at the cut end face can be provided.

[0044]

Note that, the shape of the cut end face of the workpiece 5 cut by the cutting apparatus 100 according to the present embodiment depends on the shapes of the first cutting edge and the second cutting edge. Because the first cutting edge and the second cutting edge are each in a V shape, the shape at the cut end face of the workpiece 5 is a shape having the inclined faces s3 and s4 along the V-shaped inclinations as illustrated in Figure 7, and not a vertical shear surface as illustrated in Figure 14. Therefore, for example, the cut end face of the workpiece 5 cut by the cutting apparatus 100 illustrated in Figure 1 has a shape that progressively protrudes in the direction toward the center in the sheet thickness direction.

[0045]

By making the shape of the first cutting edge and the second cutting edge a V shape, when cutting the workpiece 5, it is easy for the coating layer 5b on the surfaces of the metallic material 5a to follow the movements of the first cutting edge and the second cutting edge along the inclinations of the V shape. As a result, as illustrated in Figure 7, the coating layer 5b on the surfaces of the metallic material 5a can be caused to follow the movements up to the shear drops s1 and s2 as well as the inclined faces

s3 and s4 of the cut end face. Further, because the shear drops s1 and s2 are formed at both the front and rear surfaces of the workpiece 5 by the first cutting edge and the second cutting edge, a burr-free cut surface is formed.

[0046]

Further, the coating layers 5b on the surfaces of the metallic material 5a follows the inclinations of the first cutting edge and the second cutting edge to move to the cut end face. At such time, the amounts of the coating layers 5b covering the surfaces of the inclined faces s3 and s4 of the cut end face gradually decrease toward the fracture surface s5, as illustrated in Figure 7. By causing the coating layers 5b to cover the inclined faces s3 and s4 in this way, even if the area of the cut end face of the metallic material 5a that is coated with the coating layers 5b increases, the amounts of the coating layers 5b covering the surfaces of the metallic material 5a that are moved to the cut end face hardly increase, and thus the flat surface corrosion resistance of the workpiece 5 can be maintained.

[0047]

Note that, because the fracture surface s5 is a surface that is formed as a result of the occurrence of cracks having caused the workpiece 5 to rupture, it is difficult to cause the coating layers 5b to extend on up to the fracture surface s5. However, until the workpiece 5 is cut in a state where the front end of the first cutting edge and the front end of the second cutting edge substantially come in contact with each other to leave substantially no space, the workpiece 5 is cut along the inclined surfaces of the first cutting edge and the second cutting edge. Therefore, the proportion of the fracture surface s5 to the cut end face is slight. Therefore, even if the fracture surface s5 is not covered with the coating layers 5b, the corrosion resistance is not significantly reduced.

[0048]

In addition, by making the first cutting edge and the second cutting edge have a V shape as in the cutting apparatus 100 according to the present embodiment, it is possible to also cut, for example, a material having a tensile strength of 200 MPa or more. For example, it is possible to cut a material having a tensile strength of 270

MPa or more and, furthermore, a material having a tensile strength of 590 MPa or more.

[0049]

Further, as will be described later, by appropriately setting a cut-to-cut distance W and an amount of offset L_D between annular cutting parts in a strip running direction of a workpiece (the Y direction) (see Figure 9 described later), it is possible to cut a thick material; for example, it is possible to cut a workpiece having a sheet thickness of 2.0 mm or more. At such time, the sheet thickness of the workpiece is preferably within the range of 2.0 mm or more to 9.0 mm or less and more preferably within the range of 2.0 mm or more to 6.0 mm or less. By making the sheet thickness of the workpiece 2.0 mm or more, the workpiece can be restrained from vibrating during cutting, and the cutting can be stably performed. In addition, by making the sheet thickness of the workpiece 9.0 mm or less, the load on the blade can be reduced, and the durability of the cutting apparatus can be increased. Further, making the sheet thickness of the workpiece 9.0 mm or less causes the workpiece to rupture easily, and therefore the workpiece can be cut completely by a single cutting process.

[0050]

<3. Shape of cutting edge>

In the cutting apparatus 100 according to the present embodiment, the first cutting edge of the first annular cutting part and the second cutting edge of the second annular cutting part have the same V shape as illustrated in Figure 3. However, it suffices that each of the first cutting edge and the second cutting edge has at least a V shape, and preferably the shape of each of the first cutting edge and the second cutting edge satisfies the following conditions with regard to the shape. The shapes of the cutting edges will be described below with attention paid to the pair of cutting parts including the first annular cutting part 111 and the second annular cutting part 121 in Figure 3, and this holds true for the other pairs of cutting parts (the first annular cutting part 112 and the second annular cutting part 122, and the first annular cutting part 113 and the second annular cutting part 123). In addition, it will be assumed in the description that the cutting edges of the first annular cutting parts 111, 112, and 113

each have a front end angle of θ_1 and a front end radius of R_1 , and the cutting edges of the second annular cutting parts 121, 122, and 123 each have a front end angle θ_2 and a front end radius of R_2 .

[0051]

5 (Front end angle)

A front end angle θ_1 of the first cutting edge 111a and a front end angle θ_2 of the second cutting edge 121a are preferably made 10° or more and 120° or less. When the front end angles θ_1 and θ_2 are 10° or more, the inclination is large, and therefore the ability of the coating layers 5b to follow the movements of the cutting
10 edges improves and the corrosion resistance of the cut end face is further enhanced. Further, stress applied to the first cutting edge 111a and the second cutting edge 121a decreases, damage to the cutting edges is suppressed, and the durability of the annular cutting parts 111 and 112 improves. Furthermore, when the front end angles θ_1 and θ_2 are 120° or less, the load required to cut the workpiece 5 does not become too large,
15 and cracks are easily generated in the workpiece 5 when the cutting edges 111a and 121a are pushed in, and therefore cutting of the workpiece 5 is facilitated. Therefore, the front end angle θ_1 of the first cutting edge 111a and the front end angle θ_2 of the second cutting edge 121a are made 10° or more and 120° or less and more preferably 30° or more and 90° or less.

20 [0052]

(Front end radius)

A front end radius R_1 of the first cutting edge 111a and a front end radius R_2 of the second cutting edge 121a are preferably formed to be 0.5% or more and 35.0% or less of a sheet thickness t . When the front end radii R_1 and R_2 are each 0.5% or
25 more of the sheet thickness t , stress applied to the first cutting edge 111a and the second cutting edge 121a does not become too large, damage to the cutting edges 111a and 121a is suppressed, and the durability is enhanced. Further, when the front end radii R_1 and R_2 are each 35.0% or less of the sheet thickness t , the shape of the cut end face is good. Furthermore, since cracks are easily generated in the workpiece 5 when
30 the cutting edges 111a and 121a are pushed in, cutting of the workpiece 5 is further

facilitated. Therefore, the front end radius R_1 of the first cutting edge 111a and the front end radius R_2 of the second cutting edge 121a are made 0.5% or more and 35.0% or less of the sheet thickness t and more preferably made 3.0% or more and 10.0% or less of the sheet thickness t .

5 [0053]

In this case, the first cutting edge 111a and the second cutting edge 121a may have different shapes from each other. For example, in at least one of a case where the front end radii R_1 and R_2 are different from each other and a case where the front end angles θ_1 and θ_2 are different from each other, the first cutting edge 111a and the second cutting edge 121a will have different shapes from each other. By making the first cutting edge 111a and the second cutting edge 121a have different shapes from each other, the fracture surface ratio can be changed. Note that, the fracture surface ratio is the ratio of the fracture surface s_5 to the sheet thickness t of the workpiece 5.

[0054]

15 At such time, the ratio between the front end radius R_1 of the first cutting edge 111a and the front end radius R_2 of the second cutting edge 121a (front end radii ratio R_1/R_2) is preferably less than 100 and more preferably less than 10. Most preferable is a case where the front end radii R_1 and R_2 are equal. Further, the ratio between the front end angle θ_1 of the first cutting edge 111a and the front end angle θ_2 of the second cutting edge 121a (front end angles ratio θ_1/θ_2) is preferably less than 4 and more preferably less than 2. Most preferable is a case where the front end angles θ_1 and θ_2 are equal.

[0055]

25 By setting the front end radii ratio R_1/R_2 and the front end angles ratio θ_1/θ_2 to be within the aforementioned ranges, the fracture surface ratio can be lowered. When the first cutting edge 111a and the second cutting edge 121a make a significant difference in at least one of the front end radius or the front end angle, cutting by one of the cutting parts will proceed faster than cutting by the other, and therefore deformation of the workpiece 5 will be concentrated. As a result, rupturing of the workpiece 5 will be advanced to increase the fracture surface ratio, and consequently

30

the proportion of the cut end face coated with the coating layers 5b will decrease. Therefore, by setting the front end radii ratio R_1/R_2 and the front end angles ratio θ_1/θ_2 to be within the aforementioned ranges, the fracture surface ratio can be lowered.

[0056]

5 (Amount of deviation between front end positions)

The position of a front end 111b of the first cutting edge 111a and the position of a front end 121b of the second cutting edge 121a may be caused to match in a horizontal direction perpendicular to the direction in which the first annular cutting part 111 and the second annular cutting part 121 face each other (the sheet width
10 direction, the X direction), as illustrated in Figure 3. By causing the position of the front end 111b of the first cutting edge 111a and the position of the front end 121b of the second cutting edge 121a to match, a force in the X direction that is applied to the cutting edges 111a and 121a can be reduced, thereby enhancing the durability. Further, cracks can be generated from the cutting edge at an appropriate timing to
15 complete cutting.

[0057]

Alternatively, the position of the front end 111b of the first cutting edge 111a and the position of the front end 121b of the second cutting edge 121a may deviate from each other by an amount of deviation x in the horizontal direction. The phrase
20 "amount of deviation x between the front end positions" means the distance between the front end 111b of the first cutting edge 111a and the front end 121b of the second cutting edge 121a in the horizontal direction (the sheet width direction, the X direction). The amount of deviation between the front end positions is preferably 50% or less of the sheet thickness t. If the amount of deviation between the front end
25 positions is 50% or less of the sheet thickness t, the workpiece 5 can be cut in a manner such that desired end face properties are reliably obtained.

[0058]

Thus, it suffices to arrange the first annular cutting part 111 and the second annular cutting part 121 being the pair of cutting parts symmetrically with respect to
30 the workpiece.

[0059]

(Trimming width)

The phrase "trimming width D of the workpiece 5" refers to the length of the workpiece 5 that should be left from the cutting position in the sheet length direction (the X direction) when the workpiece 5 is cut by the cutting apparatus 100. For example, as illustrated in Figure 3, the trimming width D of the workpiece 5 is represented by the length from the cutting position to one of the end portions of the workpiece 5. In a case where the position of the cutting edge 113a of the first annular cutting part 113 and the position of the cutting edge 123a of the second annular cutting part 123 deviate with respect to each other, it suffices to take the trimming width D of the workpiece 5 as, for example, the length from an end portion of the workpiece 5 to the front end position of the cutting part on the side closer to the relevant end portion.

[0060]

The trimming width D of the workpiece 5 is equal to or greater than a front end radius R of the annular cutting part and is 5 times or less the sheet thickness t of the workpiece 5 ($R \leq D \leq 5t$) and, in particular, is preferably 3 times or less the sheet thickness t of the workpiece 5 ($R \leq D \leq 3t$). More preferably, the trimming width D of the workpiece 5 is 3 times or more the front end radius R of the annular cutting part and is equal to or less than the sheet thickness t of the workpiece 5 ($3R \leq D \leq t$). Note that, the phrase "front end radius R of the annular cutting part" refers to the front end radius R_1 of the first annular cutting parts 111, 112, and 113 or the front end radius R_2 of the second annular cutting parts 121, 122, and 123. In a case where the front end radii R_1 and R_2 are the same, $R = R_1 = R_2$. In a case where the front end radii R_1 and R_2 are different from each other, the smaller radius among the front end radius R_1 of the first annular cutting parts 111, 112, and 113 and the front end radius R_2 of the second annular cutting parts 121, 122, and 123 is taken as the front end radius R ($R = \text{Min}(R_1, R_2)$).

[0061]

By setting the trimming width D to be 5 times or less the sheet thickness t and more preferably 3 times or less the sheet thickness t, formation of the fracture surface

s5 by cutting can be suppressed, and the fracture surface ratio can be decreased. Figure 8 illustrates an example of the relation between the trimming width D and the fracture surface ratio. Figure 8 illustrates fracture surface ratios when the workpiece 5 whose sheet thickness t was 3.2 mm was cut by the cutting apparatus 100 illustrated in Figure 1 in cases where the trimming width D was set to 1.6 mm ($= 0.5t$), 3.2 mm ($= t$), 6.4 mm ($= 2t$), 12.8 mm ($= 4t$), and 16.0 mm ($= 5t$). In these cases, a galvanized steel sheet having a sheet thickness of 3.2 mm and a tensile strength of 460 MPa was used as the workpiece 5. The front end radius R of the cutting apparatus 100 was set to 0.05 mm, and the front end angle θ thereof was set to 60° . Two plots at the same trimming width D show the fracture surface ratios measured for the two pieces of the workpiece 5 cut into by the cutting apparatus 100.

[0062]

Figure 8 shows that the smaller the trimming width D is, the more the fracture surface ratio decreases. Figure 8 further shows that when the trimming width D is equal to or less than the sheet thickness t , the fracture surface ratio further decreases. In contrast, by setting the trimming width D to be equal to or greater than the front end radius R of the cutting part, particularly to be 3 times or more the front end radius R , displacement of the cutting edge by elastic deformation of a tool during cutting can be suppressed, and a good end face shape can be obtained by the cutting.

[0063]

By changing the shape of the first annular cutting parts 111, 112, and 113, the shape of the second annular cutting parts 121, 122, and 123, the amount of deviation between the front end positions of the first annular cutting parts 111, 112, and 113 and the front end positions of the second annular cutting parts 121, 122, and 123, or the trimming width D of the workpiece 5 in this way, the shape of the cut end face of the workpiece 5 cut by the cutting apparatus 100 changes, and the coverage state of the cut end face by the coating layers 5b changes. Therefore, it suffices to appropriately set the shape of the first annular cutting parts 111, 112, and 113 and the shape of the second annular cutting parts 121, 122, and 123, the amount of deviation between the front end positions of the first annular cutting parts 111, 112, and 113 and the front end

positions of the second annular cutting parts 121, 122, and 123, and the trimming width D of the workpiece 5 according to the shape of the cut end face or the corrosion resistance that is required for the workpiece 5 after cutting.

[0064]

For example, the corrosion resistance of the cut end face can be increased by making the first annular cutting parts 111, 112, and 113 and the second annular cutting parts 121, 122, and 123 have the same shape and causing the front end positions of the annular cutting parts to match so that the first annular cutting parts 111, 112, and 113 and the second annular cutting parts 121, 122, and 123 are arranged symmetrically with respect to the workpiece 5. This is because the cut end face will be symmetric with respect to the center position of the sheet thickness, and the extent to which the coating layer 5b on the bottom surface side of the workpiece 5 extends onto the inclined face s2 will be approximately equal to the extent to which the coating layer 5b on the top surface side of the workpiece 5 extends onto the inclined face s4.

[0065]

Further, for example, in the case of welding the cut end face, it is desirable that the cut end face be flat from the viewpoint of facilitating the welding work. In this case, the first annular cutting parts 111, 112, and 113 and the second annular cutting parts 121, 122, and 123 may have different V shapes to improve the flatness of the cut end face.

[0066]

(Roll diameter of annular cutting part)

The larger the roll diameter (diameter) of each of the first annular cutting part 111 and the second annular cutting part 121 is, the more the cut end face of the workpiece 5 can be coated with the coating layers 5b. The roll diameter of each of the first annular cutting part 111 and the second annular cutting part 121 is 50 mm or more and preferably 400 mm or more. The larger the roll diameter is, the more hardly the plating is pushed in the strip running direction of the workpiece 5 when the workpiece 5 is cut, and therefore the amount of plating covering the inclined faces can be increased. Note that, the upper limit of the roll diameter is not limited to a

particular diameter and may be 3000 mm with consideration given to the size of the cutting apparatus 100 or the workpiece 5.

[0067]

(Distance between annular cutting parts)

5 As illustrated in Figure 3, in a case where the cutting apparatus 100 is provided with a plurality of pairs of cutting parts, the cut-to-cut distance W, which is a distance between cutting parts adjacent to each other in the sheet width direction (the X direction), is 200 mm or more and preferably 500 mm or more. By making the cut-to-cut distance W 200 mm or more, even in a case where the workpiece 5 is cut at

10 two or more places by a single cutting process, a distance between the cutting places of the workpiece 5 is sufficiently long, and therefore a poor rupture due to no room for the material to retreat can be eliminated. Note that, the upper limit of the cut-to-cut distance W is not limited to a particular distance and may be 10000 mm with consideration given to the size of the cutting apparatus 100 or the workpiece 5.

15 [0068]

In addition, in a case where the cut-to-cut distance W cannot be secured sufficiently, it is preferable to cut the workpiece 5 at only one place in a single cutting process. If the workpiece 5 is cut at two or more places in the single cutting process, it becomes not possible for the material to retreat by pushing in of the cutting edges.

20 That is, a portion of the workpiece 5 between the cutting parts serves as a pressure stress field, which makes it difficult for the workpiece 5 to rupture. Hence, the annular cutting parts adjacent to each other in the sheet width direction (the X direction) are offset from each other in the strip running direction (the Y direction), by which it becomes possible not to cut the workpiece 5 at two or more places in the

25 single cutting process, and the workpiece 5 can be reliably cut.

[0069]

For example, Figure 9 is a schematic diagram illustrating the two roll parts of the upper rotary part 110A of the cutting apparatus 100A illustrated in Figure 4 when seen in plan view. As illustrated in Figure 9, the annular cutting parts 111 and 113

30 adjacent to each other in the sheet width direction (the X direction) are offset from

each other in the strip running direction (the Y direction) by the amount of offset L_D , by which it becomes possible not to cut the workpiece 5 at two or more places in the single cutting process. The amount of offset L_D is preferably 1 mm or more and more preferably 4 mm or more.

5 [0070]

(Height of cutting parts)

It suffices to set a height h_1 of the first cutting edge 111a and a height h_2 of the second cutting edge 121a so that at least the sum of these heights ($h_1 + h_2$) is greater than the sheet thickness t of the workpiece 5.

10 [0071]

The shape of the cutting apparatus 100 according to the present embodiment and a coverage state of coating layers on a cut end face of the workpiece 5 that is cut using the cutting apparatus 100 have been described above. The cutting apparatus 100 according to the present embodiment includes the pair of cutting parts composed of the first annular cutting part 111 and the second annular cutting part 121 that have the V-shaped cutting edges 111a and 121a, respectively. By cutting the workpiece 5 with the V-shaped cutting edges 111a and 121a, the coating layer 5b on each surface of the metallic material 5a can be caused to follow the movements of the cutting edges 111a and 121a and extend onto the cut end face. The inclined faces s_2 and s_4 of the cut end face are each coated with the coating layer 5b continuously from the surface of the metallic material 5a in a manner so that the amount of the coating layer covering the cut end face decreases toward the fracture surface s_5 . Therefore, the corrosion resistance of the cut end face can be enhanced while maintaining the flat surface corrosion resistance of the workpiece 5.

25 [0072]

Note that, cutting of the workpiece 5 by the cutting apparatus 100 may be cutting carried out by performing a single cutting process or cutting carried out by performing a plurality of cutting processes. The phrase "cutting carried out by performing a plurality of cutting processes" refers to executing a cutting process in which the workpiece 5 is caused to pass between the pair of cutting parts a plurality of

times to thereby cut the workpiece 5 into two pieces. For example, in a case where the cutting apparatus 100 in Figure 1 is used, a plurality of cutting processes may be carried out such that a first cutting process is performed with the pair of cutting parts 1, a second cutting process is performed with the pair of cutting parts 2, and a third cutting process is performed with the pair of cutting parts 3. Alternatively, a plurality of cutting apparatuses may be installed in a strip running direction of a workpiece so that a plurality of cutting processes can be carried out by a single strip running. By installing cutting apparatuses in tandem in this way, it is possible to carry out a plurality of cutting processes efficiently.

[0073]

Various kinds of cut end faces can be realized by cutting the workpiece 5 by performing a plurality of cutting processes. For example, when cutting the workpiece 5 by performing a plurality of cutting processes, the front end angle θ_1 of the first cutting edge 111a and the front end angle θ_2 of the second cutting edge 121a may be made smaller gradually through the cutting processes. By this means, the portion of the cut end face coated with the coating layers 5b can be increased, and a good end face shape can be obtained.

[0074]

At this time, it is good to make the space between the first annular cutting part 111 and the second annular cutting part 121 smaller gradually through the cutting processes. By setting the space between the first annular cutting part 111 and the second annular cutting part 121 to a large amount in the initial cutting process, the ability of the coating layers 5b to follow the movements of the first cutting edge 111a and the second cutting edge 121a increases.

[0075]

For example, in a case where the workpiece 5 is cut by performing two cutting processes, a space S between the first annular cutting part 111 and the second annular cutting part 121 in the first cutting process is preferably set so as to satisfy the relational expression of the following expression (1). More preferably, the space S between the first annular cutting part 111 and the second annular cutting part 121 in the

first cutting process is set so as to satisfy the following expression (1-2). By setting the space S between the first annular cutting part 111 and the second annular cutting part 121 in the first cutting process in this way, the portion of the cut end face coated with the coating layers 5b can be increased, and a good end face shape can be obtained.

5 [0076]

$$(R_1 + R_2) \leq S \leq \{t - (R_1 + R_2)\} \quad \dots(1)$$

$$(R_1 + R_2) \times 2 \leq S \leq \{t - (R_1 + R_2) \times 2\} \quad \dots(1-2)$$

[0077]

Note that, when it is desired to reduce the load on the cutting apparatus 100 while causing the coating layers 5b to cover the cut end face after having suppressed formation of the shear drops during cutting of the workpiece 5, the front end angle θ_1 of the first cutting edge 111a and the front end angle θ_2 of the second cutting edge 121a may be made to increase gradually through the cutting processes.

[0078]

15 Further, a rotational speed of the first annular cutting part 111 and a rotational speed of the second annular cutting part 121 may be set to a speed different from a conveyance speed of the workpiece 5. When there is a difference in speed between the rotational speeds of the annular cutting parts 111 and 121 and the conveyance speed of the workpiece 5, a timing of cutting can be controlled. The larger the difference in speed, the easier the workpiece 5 is cut. Note that, the difference in speed from the rotational speeds is preferably 10% or less and further preferably 5% or less; otherwise, the load on the cutting apparatus 100 increases.

EXAMPLES

25 [0079]

A plated metallic material was adopted as a workpiece that had been subjected to a surface treatment, and the coverage states of plating at a cut end face of the plated metallic material when the plated metallic material was cut by cutting apparatuses were observed. Front photographs of the respective cut end faces of the plated metallic material cut by the cutting apparatuses are illustrated in Figure 10. Lateral

cross-sectional photographs of the respective cut end faces of the plated metallic material cut by the cutting apparatuses are illustrated in Figure 11. Figure 10 and Figure 11 show, as Examples 1 to 3, front photographs and lateral cross-sectional photographs of the cut end face of a plated metallic material when the plated metallic material was cut using the cutting apparatus 100 according to the present invention illustrated in Figure 1. A piece A and a piece B in each pair in Figure 10 illustrate two pieces of the plated metallic material separated by cutting with the cutting apparatus. Figure 11 includes front photographs of the pieces A and the pieces B illustrated in Figure 10 at center positions in a longitudinal direction.

[0080]

The plated metallic material cut with the cutting apparatus had a sheet thickness of 3.2 mm. The front end radius R_1 of the cutting edge of the first annular cutting part and the front end radius R_2 of the cutting edge of the second annular cutting part were both set to 0.05 mm in Example 1, 0.1 mm in Example 2, and 0.5 mm in Example 3. In addition, the front end angle θ_1 of the cutting edge of the first annular cutting part and the front end angle θ_2 of the cutting edge of the second annular cutting part were set to 60° , and the height h_1 of the cutting edge of the first annular cutting part and the height h_2 of the cutting edge of the second annular cutting part were set to 4 mm. The diameter of the first annular cutting part and the diameter of the second annular cutting part were set to 50 mm.

[0081]

As illustrated in Figure 10 and Figure 11, in Examples 1 to 3, although the front end radii R_1 and R_2 of the cutting edges differed, each cut end face was formed of shear drops, inclined faces, and a fracture surface, and the proportion of the inclined faces was large. Plating remained on each inclined face, and the amount of plating with which each inclined face is coated had decreased toward the center of the sheet thickness from the metallic material surface. Further, in comparison to Example 1, in Examples 2 and 3 in which the front end radii R_1 and R_2 of the cutting edges were large, the rate of decrease in the amount of plating up to the vicinity of the center of the sheet thickness from the metallic material surface on the inclined faces was small, and

a greater amount of the plating had followed the movements of the cutting edges. For example, Figure 12 illustrates an enlarged image of the cut end face of the workpiece in Example 3. As illustrated in Figure 12, it is found that, at an inclined face of the workpiece, a surface of the metallic material is coated with a coating layer. By cutting a plated metallic material using the cutting apparatus according to the present invention in this way, it is possible to extensively cover the cut end face with the plating.

[0082]

Whilst preferred embodiments of the present invention have been described in detail above with reference to the accompanying drawings, the present invention is not limited to the above examples. It is clear that a person having common knowledge in the field of the art to which the present invention pertains will be able to contrive various examples of changes and modifications within the category of the technical idea described in the appended claims, and it should be understood that they also naturally belong to the technical scope of the present invention.

[0083]

For example, although in the above embodiments the workpiece is a plated steel sheet, the present invention is not limited to this example. The workpiece may be any kind of workpiece formed by coating the surface of a base material with a coating material. For example, a metallic material such as a steel sheet may be used as a base material, and a material composed of Zn, Al or an alloy of these elements, an oxide coating, a painting material, a resin material or the like may be used as a coating material. Consequently, the workpiece may be a coated steel sheet obtained by coating the surface of a metallic material as a base material with paint, or may be a film-laminated steel sheet obtained by laminating a film on a steel sheet. Alternatively, it is also possible to produce a cut article from a clad material composed of a base material and a coating material. Examples of the clad material include an Ni-clad copper material having a Cu sheet as a base material and an Ni sheet as a coating material.

[0084]

Note that, the workpiece is not limited to a material covered with only one layer, and may be covered with multiple layers. For example, the surface of the aforementioned plated steel sheet may be subjected to a chemical treatment, painting, laminating or the like.

5 [0085]

Furthermore, according to the cutting method of the present invention, it is possible to also similarly form an article obtained by cutting a workpiece in which a resin material, such as plastic, was used as a base material, and a metallic material such as Cu, Cr, Ag, Au or Pt was used as a coating material.

10 [0086]

When a resin material, such as plastic, that is covered with a metal is cut, electrical conductivity of the end face is lost. Further, when the exposed proportion of the resin is high, it is easy to become charged, and hence the occurrence of sparking or the like is a concern. Therefore, by cutting such a resin material by using the cutting method described above, it is possible to improve the electrical conductivity of the cut end face and to prevent charging.

[0087]

Further, in the case of a clad material, the required purpose when cutting will differ depending on the combination with the workpiece as well as the intended use.

20 However, by cutting the workpiece by using the aforementioned cutting method, the corrosion resistance and chemical resistance and the like of the base material of the cut end face can be improved. Further, the electrical conductivity, thermal conductivity, magnetism and the like of one part or all of the cut end face can be improved as compared with the conventional cutting method.

25 [0088]

In the case of coating films and laminates, by cutting the workpiece using the aforementioned cutting method, as well as improving the corrosion resistance of the base material, it is also possible to suppress the occurrence of bulging underneath the coating film, improve the appearance because the base material is not exposed, and to improve the insulation property of one part of or all of the cut end face.

30

[0089]

Thus, by cutting a workpiece by using the aforementioned cutting method, it is possible to cause a function which a coating material possesses at a flat surface to also be imparted at a cut end face. Note that, a function which a coating material possesses is not limited to the aforementioned example, and the function of the coating material can be exhibited according to the intended use of the coating material. In other words, by means of the cutting method according to the present embodiment, when cutting a workpiece, the occurrence of a situation in which the performance which the workpiece has is reduced after the cutting can be suppressed. This similarly applies with respect to cutting of an untreated material, and not only to cutting of a workpiece that was subjected to a surface treatment. For example, by using the cutting method according to the present embodiment, irrespective of the presence or absence of a coating material, a decrease in the fatigue life of the cut workpiece can be suppressed.

[0090]

Further, in the embodiment, the cutting apparatus may cut a workpiece along a curve and can cut a workpiece into any shape such as a round shape.

[0091]

Note that, the following configurations are also included in the technical scope of the present invention.

(1) A cutting method for cutting a workpiece subjected to a surface treatment, using a cutting apparatus, wherein

the cutting apparatus includes

at least one pair of cutting parts including a first annular cutting part and a second annular cutting part,

a first cutting edge provided on an outer edge of the first annular cutting part and a second cutting edge provided on an outer edge of the second annular cutting part each have a V-shaped radial-direction profile, and

the workpiece is cut by causing the workpiece to pass between the first cutting edge and the second cutting edge facing each other and pushing the cutting edges into

the workpiece.

(2) The cutting method according to the above (1), wherein the first annular cutting part and the second annular cutting part are arranged such that a front end position of the first cutting edge and a front end position of the second cutting edge match.

(3) The cutting method according to the above (1), wherein when the first cutting edge of the first annular cutting part and the second cutting edge of the second annular cutting part are caused to face each other, an amount of deviation between the front end position of the first cutting edge and the front end position of the second cutting edge is made 50% or less of a sheet thickness.

(4) The cutting method according to any one of the above (1) to (3), wherein the first cutting edge of the first annular cutting part and the second cutting edge of the second annular cutting part have the same shape and are arranged symmetrically with respect to the workpiece.

(5) The cutting method according to any one of the above (1) to (4), wherein cutting of the workpiece is carried out by performing a plurality of cutting processes.

(6) The cutting method according to the above (5), wherein in cutting of the workpiece by performing the plurality of cutting processes, a front end angle θ_1 of the first cutting edge and a front end angle θ_2 of the second cutting edge may be made smaller gradually through the cutting processes.

(7) The cutting method according to the above (5) or (6), wherein in a case where the workpiece is cut by performing two cutting processes, when a front end radius of the first cutting edge is defined as R_1 , a front end radius of the second cutting edge is defined as R_2 , and a sheet thickness of the workpiece is defined as t , a space S between the first cutting edge and the second cutting edge in a first cutting process satisfies expression (a) below.

$$(R_1 + R_2) \leq S \leq \{t - (R_1 + R_2)\} \quad \dots(a)$$

(8) The cutting method according to the above (7), wherein in a case where the workpiece is cut by performing two cutting processes, the space S between the first cutting edge and the second cutting edge in the first cutting process satisfies expression

(b) below.

$$(R_1 + R_2) \times 2 \leq S \leq \{t - (R_1 + R_2) \times 2\} \quad \dots(b)$$

(9) The cutting method according to any one of the above (1) to (8), wherein a trimming width of the workpiece is a distance between one of end portions

5 of the workpiece and a cutting position of the workpiece, and

when a front end radius of the first annular cutting part is defined as R_1 , a front end radius of the second annular cutting part is defined as R_2 , and a sheet thickness of the workpiece is defined as t , a trimming width D of the workpiece satisfies expression (c) below.

10 $R \leq D \leq 5t \quad \dots(c)$

$$R = \text{Min}(R_1, R_2)$$

(10) The cutting method according to the above (9), wherein the trimming width D of the workpiece satisfies expression (d) below.

$$3R \leq D \leq t \quad \dots(d)$$

15 (11) The cutting method according to any one of the above (1) to (10), wherein the workpiece is cut at only one place in a single cutting process.

(12) The cutting method according to any one of the above (1) to (11), wherein in a case where the number of the at least one pair of cutting parts provided in the cutting apparatus is more than one, a distance W between the cutting parts adjacent

20 to each other in a sheet width direction is 200 mm or more.

(13) The cutting method according to the above (12), wherein in a case where the number of the at least one pair of cutting parts provided in the cutting apparatus is more than one, the distance W between the cutting parts adjacent to each other in the sheet width direction is 500 mm or more.

25 (14) The cutting method according to any one of the above (1) to (13), wherein a diameter of each of the first annular cutting part and the second annular cutting part is 50 mm or more.

(15) The cutting method according to the above (14), wherein the diameter of each of the first annular cutting part and the second annular cutting part is 400 mm or

30 more.

(16) The cutting method according to any one of the above (1) to (15), wherein a rotational speed of the first annular cutting part and a rotational speed of the second annular cutting part are set to a speed different from a conveyance speed of the workpiece.

5 (17) The cutting method according to any one of the above (1) to (16), wherein the workpiece is a material having a tensile strength of 270 MPa or more.

(18) The cutting method according to the above (17), wherein the workpiece is a material having a tensile strength of 590 MPa or more.

10 (19) The cutting method according to any one of the above (1) to (18), wherein the workpiece is a plated metal sheet.

(20) A cutting apparatus comprising:

a pair of cutting parts including a first annular cutting part and a second annular cutting part;

15 a first shaft part and a second shaft part, the first shaft part supporting the first annular cutting part, the second shaft part supporting the second annular cutting part;

supporting parts that rotatably support both ends of each of the first shaft part and the second shaft part; and

a space adjusting unit that adjusts a space between the first annular cutting part and the second annular cutting part, wherein

20 a first cutting edge provided on an outer edge of the first annular cutting part and a second cutting edge provided on an outer edge of the second annular cutting part face each other and each have a V-shaped radial-direction profile, and

25 the space adjusting unit adjusts the space between the first annular cutting part and the second annular cutting part in accordance with a sheet thickness of a workpiece.

REFERENCE SIGNS LIST

[0092]

1, 2, 3 Pair of Cutting Parts

5 Workpiece

30 5a Metallic Material

	5b	Coating Layer
	100	Cutting Apparatus
	101	Base
	103a, 103b	Supporting Part
5	104a, 104b	Driving Unit
	105a, 105b, 107a, 107b	Chock
	109a, 109b	Pressing Device
	110	Upper Rotary Part
	111, 112, 113	First Annular Cutting Part
10	111a, 112a, 113a	First Cutting Edge
	111b, 112b, 113b	Front End
	115	First Shaft Part
	120	Lower Rotary Part
	121, 122, 123	Second Annular Cutting Part
15	121a, 122a, 123a	Second Cutting Edge
	121b, 122b, 123b	Front End
	125	Second Shaft Part
	131, 133	Sleeve
	1110	Twin-Edged Roll

CLAIMS

[Claim 1]

A cutting method for cutting a workpiece using a cutting apparatus, wherein
5 the cutting apparatus includes

at least one pair of cutting parts including a first annular cutting part and a
second annular cutting part,

a first cutting edge provided on an outer edge of the first annular cutting part
and a second cutting edge provided on an outer edge of the second annular cutting part
10 each have a V-shaped radial-direction profile,

a front end angle θ_1 of the first cutting edge and a front end angle θ_2 of the
second cutting edge being 10° or more and 120° or less,

a front end radius R_1 of the first cutting edge and a front end radius R_2 of the
second cutting edge being 0.5% or more and 35.0% or less of a sheet thickness, and

15 the workpiece is cut by causing the workpiece to pass between the first cutting
edge and the second cutting edge facing each other and pushing the cutting edges into
the workpiece.

[Claim 2]

The cutting method according to claim 1, wherein the workpiece is a
20 multi-layer material formed by coating a surface of a base material with a coating
material.

[Claim 3]

The cutting method according to claim 1 or 2, wherein cutting of the
workpiece is carried out by performing a plurality of cutting processes.

25 [Claim 4]

The cutting method according to claim 3, wherein in cutting of the workpiece
by performing the plurality of cutting processes, the front end angle θ_1 of the first
cutting edge and the front end angle θ_2 of the second cutting edge are made smaller
gradually through the cutting processes.

30 [Claim 5]

The cutting method according to claim 3 or 4, wherein in a case where the workpiece is cut by performing two cutting processes, when a front end radius of the first cutting edge is defined as R_1 , a front end radius of the second cutting edge is defined as R_2 , and a sheet thickness of the workpiece is defined as t , a space S between the first cutting edge and the second cutting edge in a first cutting process satisfies expression (1) below.

$$(R_1 + R_2) \leq S \leq \{t - (R_1 + R_2)\} \quad \dots(1)$$

[Claim 6]

The cutting method according to any one of claims 1 to 5, wherein a trimming width of the workpiece is a distance between one of end portions of the workpiece and a cutting position of the workpiece, and

when a front end radius of the first annular cutting part is defined as R_1 , a front end radius of the second annular cutting part is defined as R_2 , and a sheet thickness of the workpiece is defined as t , a trimming width D of the workpiece satisfies expression (2) below.

$$R \leq D \leq 3t \quad \dots(2)$$

$$R = \text{Min}(R_1, R_2)$$

[Claim 7]

The cutting method according to any one of claims 1 to 6, wherein an amount of offset L_D between annular cutting parts in a strip running direction is 1 mm or more, and the workpiece is cut at only one place in a single cutting process.

[Claim 8]

The cutting method according to any one of claims 1 to 7, wherein in a case where the number of the at least one pair of cutting parts provided in the cutting apparatus is more than one, a distance W between the cutting parts adjacent to each other in a sheet width direction is 200 mm or more.

[Claim 9]

The cutting method according to any one of claims 1 to 8, wherein a diameter of each of the first annular cutting part and the second annular cutting part is 50 mm or

more.