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### CUTTING INSERT AND PROCESSING METHOD

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#### Abstract

A cutting insert includes a rake face, a flank face, and a cutting edge constituted of a ridgeline between the rake face and the flank face. The cutting edge has a first cutting edge portion for corner processing, a second cutting edge portion for low cut-in pulling processing, a third cutting edge portion for high cut-in pulling processing, a fourth cutting edge portion for finished-surface processing, a first connection cutting edge portion, a second connection cutting edge portion, and a third connection cutting edge portion. The fourth cutting edge portion is disposed between the first cutting edge portion and the second cutting edge portion. The second cutting edge portion is disposed between the fourth cutting edge portion and the third cutting edge portion. Each of the first cutting edge portion, the second cutting edge portion, and the fourth cutting edge portion has a curved shape.

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## Background/Summary

### TECHNICAL FIELD

[0001] The present disclosure relates to a cutting insert and a processing method.

### BACKGROUND ART

[0002] WO 2019/087496 (PTL 1) discloses a cutting insert having a rake face, a flank face, and a chamfer disposed between the rake face and the flank face.

### CITATION LIST

#### Patent Literature

[0003] PTL 1: WO 2019/087496

### SUMMARY OF INVENTION

#### Technical Problem

[0004] For example, when high-efficiency processing for hardened steel is performed, cutting resistance becomes high, with the result that breakage of a cutting edge is likely to occur.

Therefore, it is difficult to improve a tool life of a cutting insert.

[0005] It is an object of the present disclosure to provide a cutting insert to improve a tool life.

#### Solution to Problem

[0006] A cutting insert according to the present disclosure has a surface involved in cutting, the surface being composed of a cBN-based sintered material, a diamond-based sintered material, a ceramic, a cermet, or a cemented carbide, the cutting insert including: a rake face; a flank face; and a cutting edge constituted of a ridgeline between the rake face and the flank face. The cutting edge has a first cutting edge portion for corner processing, a second cutting edge portion for low cut-in pulling processing, a third cutting edge portion for high cut-in pulling processing, a fourth cutting edge portion for finished-surface processing, a first connection cutting edge portion that connects the first cutting edge portion and the fourth cutting edge portion, a second connection cutting edge portion that connects the second cutting edge portion and the fourth cutting edge portion, and a third connection cutting edge portion that connects the second cutting edge portion and the third cutting edge portion. The fourth cutting edge portion is disposed between the first cutting edge portion and the second cutting edge portion. The second cutting edge portion is disposed between the fourth cutting edge portion and the third cutting edge portion. Each of the first cutting edge portion, the second cutting edge portion, and the fourth cutting edge portion has a curved shape. A curvature radius of the first cutting edge portion is 0.1 mm or more and 2.4 mm or less. A curvature radius of the second cutting edge portion is 3 mm or more. A curvature radius of the fourth cutting edge portion is 3 mm or more. The third cutting edge portion has a straight line shape. Each of the first connection cutting edge portion, the second connection cutting edge portion and the third connection cutting edge portion has a curved shape.

#### Advantageous Effects of Invention

[0007] According to the present disclosure, it is possible to provide a cutting insert to improve a tool life.

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## Description

### BRIEF DESCRIPTION OF DRAWINGS

[0008] FIG. 1 is a schematic perspective view showing a configuration of a cutting insert according to a first embodiment.

[0009] FIG. 2 is a schematic plan view showing a configuration of a cutting tool according to the first embodiment.

[0010] FIG. 3 is an enlarged schematic diagram of a region III in FIG. 1.

[0011] FIG. 4 is a schematic cross sectional view along a line IV-IV of FIG. 2.

[0012] FIG. 5 is a schematic perspective view showing a configuration of a cutting insert according to a second embodiment.

[0013] FIG. 6 is a schematic plan view showing the configuration of the cutting insert according to the second embodiment.

[0014] FIG. 7 is a schematic cross sectional view along a line VII-VII of FIG. 6.

[0015] FIG. 8 is a schematic cross sectional view along a line VIII-VIII of FIG. 6.

[0016] FIG. 9 is a schematic cross sectional view along a line IX-IX of FIG. 6.

[0017] FIG. 10 is a schematic cross sectional view along a line X-X of FIG. 6.

[0018] FIG. 11 is a schematic cross sectional view along a line XI-XI of FIG. 6.

[0019] FIG. 12 is a schematic diagram showing a first processing method according to the present embodiment.

[0020] FIG. 13 is an enlarged schematic diagram showing a processing state.

[0021] FIG. 14 is a schematic diagram showing a relation between a cut-in amount and a lateral cutting edge angle of the cutting edge.

[0022] FIG. 15 is a schematic side view showing a lateral rake angle of the cutting edge.

[0023] FIG. 16 is a schematic diagram showing a second processing method according to the present embodiment.

## DETAILED DESCRIPTION

### Description of Embodiments of the Present Disclosure

[0024] First, embodiments of the present disclosure (also referred to as “the present embodiment”) will be described.

[0025] (1) A cutting insert **100** according to the present disclosure has a surface involved in cutting, the surface being composed of a cBN-based sintered material, a diamond-based sintered material, a ceramic, a cermet, or a cemented carbide, cutting insert **100** including: a rake face **50**, a flank face **70**, and a cutting edge **10** constituted of a ridgeline **20** between rake face **50** and flank face **70**. Cutting edge **10** has a first cutting edge portion **1** for corner processing, a second cutting edge portion **2** for low cut-in pulling processing, a third cutting edge portion **3** for high cut-in pulling processing, a fourth cutting edge portion **4** for finished-surface processing, a first connection cutting edge portion **11** that connects first cutting edge portion **1** and fourth cutting edge portion **4**, a second connection cutting edge portion **12** that connects second cutting edge portion **2** and fourth cutting edge portion **4**, and a third connection cutting edge portion **13** that connects second cutting edge portion **2** and third cutting edge portion **3**. Fourth cutting edge portion **4** is disposed between first cutting edge portion **1** and second cutting edge portion **2**. Second cutting edge portion **2** is disposed between fourth cutting edge portion **4** and third cutting edge portion **3**. Each of first cutting edge portion **1**, second cutting edge portion **2**, and fourth cutting edge portion **4** has a curved shape. A curvature radius of first cutting edge portion **1** is 0.1 mm or more and 2.4 mm or less. A curvature radius of second cutting edge portion **2** is 3 mm or more. A curvature radius of fourth cutting edge portion **4** is 3 mm or more. Third cutting edge portion **3** has a straight line shape. Each of first connection cutting edge portion **11**, second connection cutting edge portion **12**, and third connection cutting edge portion **13** has a curved shape.

[0026] (2) In cutting insert **100** according to (1), a curvature radius of each of first connection cutting edge portion **11**, second connection cutting edge portion **12**, and third connection cutting edge portion **13** may be 0.2 mm or more.

[0027] (3) In cutting insert **100** according to (1) or (2), a flank angle of each of first cutting edge portion **1**, second cutting edge portion **2**, third cutting edge portion **3**, and fourth cutting edge portion **4** may be 3° or more and 20° or less.

[0028] (4) In cutting insert **100** according to any one of (1) to (3), flank face **70** may have a restraint surface **71** to be restrained by a holder. When an apex angle of second cutting edge portion **2** is defined as a first angle  $\theta_8$  and an apex angle of a ridgeline between restraint surface **71** and rake face **50** is defined as a second angle  $\theta_9$ , second angle  $\theta_9$  may be smaller than first angle  $\theta_8$ . Second angle  $\theta_9$  may be  $30^\circ$  or more and  $80^\circ$  or less.

[0029] (5) In cutting insert **100** according to any one of (1) to (3), flank face **70** may have a restraint surface **71** to be restrained by a holder. When an apex angle of second cutting edge portion **2** is defined as a first angle  $\theta_8$  and an apex angle of a ridgeline between restraint surface **71** and rake face **50** is defined as a second angle  $\theta_9$ , second angle  $\theta_9$  may be smaller than first angle  $\theta_8$ . First angle  $\theta_8$  may be  $35^\circ$  or more and  $85^\circ$  or less.

[0030] (6) In cutting insert **100** according to (4) or (5), a flank angle of restraint surface **71** may be  $0^\circ$ .

[0031] (7) A processing method according to one embodiment of the present disclosure is a processing method using the cutting insert according to any one of (1) to (6), wherein in pulling processing for processing a workpiece using second cutting edge portion **2**, a lateral rake angle of second cutting edge portion **2** may be  $-20^\circ$  or more and  $20^\circ$  or less.

[0032] (8) In the processing method according to (7), in pulling processing for processing a workpiece using third cutting edge portion **3**, a lateral rake angle of third cutting edge portion **3** may be  $-20^\circ$  or more and  $20^\circ$  or less.

[0033] (9) In the processing method according to (7) or (8), second cutting edge portion **2** may be located within a range of 0.15 mm or less from a position closest to the workpiece in a direction perpendicular to a rotation axis. In the pulling processing for processing the workpiece using second cutting edge portion **2**, a lateral cutting edge angle of second cutting edge portion **2** may be  $70^\circ$  or more and  $89^\circ$  or less.

[0034] (10) In the processing method according to (7) or (8), third cutting edge portion **3** may be located within a range of 0.05 mm or more and 0.5 mm or less from a position closest to the workpiece in a direction perpendicular to a rotation axis. A lateral cutting edge angle of third cutting edge portion **3** may be  $60^\circ$  or more and  $85^\circ$  or less.

[0035] (11) In the processing method according to any one of (7) to (10), a minimum value of a lateral cutting edge angle of second cutting edge portion **2** may be the same as a lateral cutting edge angle of third cutting edge portion **3**.

[0036] Specific examples of a cutting insert according to an embodiment of the present disclosure will be described below with reference to figures. In the below-described figures, the same or corresponding portions are denoted by the same reference characters and will not be described repeatedly.

#### First Embodiment

[0037] FIG. **1** is a schematic perspective view showing a configuration of a cutting insert according to a first embodiment. As shown in FIG. **1**, cutting insert **100** according to the first embodiment has a cutting edge member **6** and a base metal **7**. Cutting edge member **6** is attached to base metal **7**. Cutting edge member **6** is involved in cutting. The shape of base metal **7** when viewed in a plan view is not particularly limited, but is, for example, a rhombic shape. Cutting edge member **6** is joined to an acute corner portion of base metal **7**. Base metal **7** is composed of, for example, a cemented carbide, a cermet, or the like. Cutting insert **100** according to the present embodiment is formed by joining cutting edge member **6** to the acute corner portion of base metal **7**; however, a whole of cutting insert **100** may be constituted of cutting edge member **6**.

[0038] The present disclosure is also applied to cutting inserts **100** having polygonal shapes other than the rhombic shape. Since the shapes of the cutting edges are the same thereamong, only cutting insert **100** having the rhombic shape is illustrated. The acute corner portion of base metal **7** is provided with a counterbore portion **8** obtained by partially depressing a portion of the upper surface. Cutting edge member **6** is joined to base metal **7** at counterbore portion **8** by joining means

such as brazing.

[0039] Cutting edge member **6** is composed of a cBN-based sintered material, a diamond-based sintered material, a ceramic, a cermet, or a cemented carbide. The cBN-based sintered material is a sintered material including 10% or more and 99.9% or less of cBN (cubic boron nitride) in volume ratio. The diamond-based sintered material is a sintered material including 10% or more and 99.9% or less of diamond in volume ratio. The ceramic is not particularly limited; however, a ceramic such as alumina (Al.sub.2O.sub.3), silicon nitride (Si.sub.3N.sub.4), or titanium carbide (TiC) can be suitably used, for example. The cermet is not particularly limited; however, a nitride-based cermet or a carbide-based cermet can be suitably used, for example.

[0040] Cutting insert **100** according to the present embodiment has a rake face **50**, a flank face **70**, a cutting edge **10**, and a bottom surface **60**. Cutting edge **10** is constituted of a ridgeline **20** between rake face **50** and flank face **70**. Ridgeline **20** has two cutting edges **10**, two first ridgeline portions **21**, and two second ridgeline portions **22**. Each of cutting edges **10** is a part of ridgeline **20**. Flank face **70** has a first flank face portion **30**, a second flank face portion **40**, and a restraint surface **71**. First flank face portion **30** is contiguous to cutting edge **10**. Second flank face portion **40** is contiguous to each of first flank face portion **30** and bottom surface **60**.

[0041] Cutting edge **10** has a first cutting edge portion **1** for corner processing, a second cutting edge portion **2** for low cut-in pulling processing, a third cutting edge portion **3** for high cut-in pulling processing, and a fourth cutting edge portion **4** for finished-surface processing. Fourth cutting edge portion **4** is disposed between first cutting edge portion **1** and second cutting edge portion **2**. Second cutting edge portion **2** is disposed between fourth cutting edge portion **4** and third cutting edge portion **3**.

[0042] FIG. **2** is a schematic plan view showing a configuration of a cutting tool according to the first embodiment. The schematic plan view shown in FIG. **2** shows a state when viewed along a straight line perpendicular to rake face **50**.

[0043] As shown in FIG. **2**, first cutting edge portion **1** has a curved shape. First cutting edge portion **1** is curved to protrude outward. First cutting edge portion **1** is a corner cutting edge portion. The curvature radius of first cutting edge portion **1** is 0.1 mm or more and 2.4 mm or less. The curvature radius of first cutting edge portion **1** is not particularly limited, but may be 0.2 mm or more and 2.2 mm or less, 0.4 mm or more and 2.0 mm or less, or 0.6 mm or more and 1.8 mm or less.

[0044] Fourth cutting edge portion **4** has a curved shape. The curvature radius of fourth cutting edge portion **4** is 3 mm or more. The curvature radius of fourth cutting edge portion **4** is not particularly limited, but may be 5 mm or more, 10 mm or more, 20 mm or more, or 40 mm or more. The curvature radius of fourth cutting edge portion **4** may be 80 mm or less, 70 mm or less, or 60 mm or less.

[0045] Second cutting edge portion **2** has a curved shape. The curvature radius of second cutting edge portion **2** is 3 mm or more. The curvature radius of second cutting edge portion **2** is not particularly limited, but may be 5 mm or more, 10 mm or more, 20 mm or more, or 40 mm or more. The curvature radius of second cutting edge portion **2** may be 80 mm or less, 70 mm or less, or 60 mm or less. The curvature radius of second cutting edge portion **2** may be different from or the same as the curvature radius of fourth cutting edge portion **4**.

[0046] Third cutting edge portion **3** has a straight line shape. The length of third cutting edge portion **3** may be longer than the length of second cutting edge portion **2**. The length of second cutting edge portion **2** is a length measured when second cutting edge portion **2** having the curved shape is formed into a straight line shape. The length of third cutting edge portion **3** is, for example, 0.5 mm or more and 5.0 mm or less.

[0047] As shown in FIG. **2**, rake face **50** has a first rake face portion **51** and a second rake face portion **52**. First rake face portion **51** is constituted of cutting edge member **6**. Second rake face portion **52** is constituted of base metal **7**. A through hole **5** is formed in second rake face portion **52**.

[0048] The cutting insert according to the present embodiment has two cutting edges **10**. When viewed along a straight line perpendicular to rake face **50**, through hole **5** is located between two cutting edges **10**. Each of two cutting edges **10** may have one first cutting edge portion **1**, two second cutting edge portions **2**, two third cutting edge portions **3**, and two fourth cutting edge portions **4**. First cutting edge portion **1** may be located between two fourth cutting edge portions **4**.

[0049] When viewed along the straight line perpendicular to rake face **50**, two cutting edges **10** may have shapes line-symmetrical with respect to a straight line (diagonal line of the cutting insert) extending through two first cutting edge portions **1**. Two cutting edges **10** may have shapes two-fold symmetrical with respect to an axis extending through through hole **5**.

[0050] As shown in FIG. **2**, each of first ridgeline portions **21** and second ridgeline portions **22** is constituted of base metal **7**. Cutting edge **10** is constituted of cutting edge member **6**. Two first ridgeline portions **21** face each other. Similarly, two second ridgeline portions **22** face each other. When viewed along the straight line perpendicular to rake face **50**, each of two first ridgeline portions **21** has a straight line shape and each of two second ridgeline portions **22** has a straight line shape.

[0051] A first one of two third cutting edge portions **3** may be contiguous to first ridgeline portion **21**, and a second one of two third cutting edge portions **3** may be contiguous to second ridgeline portion **22**. The length of first ridgeline portion **21** may be longer than the length of third cutting edge portion **3** contiguous to first ridgeline portion **21**. The length of second ridgeline portion **22** may be longer than the length of third cutting edge portion **3** contiguous to second ridgeline portion **22**.

[0052] As shown in FIG. **2**, the apex angle of second cutting edge portion **2** is defined as a first angle  $\theta_8$ . Specifically, when viewed along the straight line perpendicular to rake face **50**, first angle  $\theta_8$  is an angle formed by straight lines extending through both ends of each of two second cutting edge portions **2**. Flank face **70** has restraint surface **71** to be restrained by a holder (see FIG. **1**). The flank angle of restraint surface **71** is, for example,  $0^\circ$ . The flank angle of restraint surface **71** is an angle of restraint surface **71** with respect to a plane perpendicular to rake face **50**. The apex angle of a ridgeline between restraint surface **71** and rake face **50** is defined as a second angle  $\theta_9$ . Specifically, when viewed along the straight line perpendicular to rake face **50**, second angle  $\theta_9$  is an angle formed by first ridgeline portion **21** and second ridgeline portion **22**.

[0053] First angle  $\theta_8$  is, for example,  $70^\circ$ . First angle  $\theta_8$  may be  $35^\circ$  or more and  $850$  or less,  $45^\circ$  or more and  $80^\circ$  or less, or  $55^\circ$  or more and  $75^\circ$  or less. Second angle  $\theta_9$  is smaller than first angle  $\theta_8$ . Second angle  $\theta_9$  is, for example,  $55^\circ$ . Second angle  $\theta_9$  may be  $30^\circ$  or more and  $80^\circ$  or less,  $35^\circ$  or more and  $70^\circ$  or less, or  $40^\circ$  or more and  $60^\circ$  or less.

[0054] At a contact point between first ridgeline portion **21** and third cutting edge portion **3**, third cutting edge portion **3** may be inclined with respect to first ridgeline portion **21**. Similarly, at a contact point between second ridgeline portion **22** and third cutting edge portion **3**, third cutting edge portion **3** may be inclined with respect to second ridgeline portion **22**. The apex angle of third cutting edge portion **3** may be smaller than first angle  $\theta_8$ . The apex angle of third cutting edge portion **3** may be larger than second angle  $\theta_9$ . The apex angle of third cutting edge portion **3** is an angle formed by two third cutting edge portions **3** when viewed along a straight line perpendicular to rake face **50**.

[0055] FIG. **3** is an enlarged schematic view of a region III in FIG. **1**. As shown in FIG. **3**, cutting edge **10** has a first connection cutting edge portion **11**, a second connection cutting edge portion **12**, and a third connection cutting edge portion **13**. First connection cutting edge portion **11** connects first cutting edge portion **1** and fourth cutting edge portion **4**. First connection cutting edge portion **11** is located between first cutting edge portion **1** and fourth cutting edge portion **4**. Second connection cutting edge portion **12** connects second cutting edge portion **2** and fourth cutting edge portion **4**. Second connection cutting edge portion **12** is located between second cutting edge portion **2** and fourth cutting edge portion **4**. Third connection cutting edge portion **13** connects

second cutting edge portion 2 and third cutting edge portion 3. Third connection cutting edge portion 13 is located between second cutting edge portion 2 and third cutting edge portion 3. [0056] When viewed along the straight line perpendicular to rake face 50, each of first connection cutting edge portion 11, second connection cutting edge portion 12, and third connection cutting edge portion 13 has a curved shape. Each of first connection cutting edge portion 11, second connection cutting edge portion 12, and third connection cutting edge portion 13 is curved to protrude outward. The curvature radius of third connection cutting edge portion 13 may be larger than the curvature radius of each of first connection cutting edge portion 11 and second connection cutting edge portion 12.

[0057] The curvature radius of each of first connection cutting edge portion 11, second connection cutting edge portion 12, and third connection cutting edge portion 13 may be, for example, 0.2 mm or more. The curvature radius of each of first connection cutting edge portion 11, second connection cutting edge portion 12, and third connection cutting edge portion 13 may be, for example, 0.3 mm or more, or 0.5 mm or more. The curvature radius of each of first connection cutting edge portion 11, second connection cutting edge portion 12, and third connection cutting edge portion 13 may be less than 3 mm, or less than 2 mm.

[0058] First connection cutting edge portion 11 and each of first cutting edge portion 1 and fourth cutting edge portion 4 adjacent thereto may have different curvature radii. Second connection cutting edge portion 12 and each of second cutting edge portion 2 and fourth cutting edge portion 4 adjacent thereto may have different curvature radii. Third connection cutting edge portion 13 and each of second cutting edge portion 2 and third cutting edge portion 3 adjacent thereto may have different curvature radii.

[0059] As shown in FIG. 3, first flank face portion 30 has a first flank face region 31, a second flank face region 32, a third flank face region 33, a fourth flank face region 34, a fifth flank face region 35, a sixth flank face region 36, and a seventh flank face region 37. First flank face region 31 is contiguous to first cutting edge portion 1. Second flank face region 32 is contiguous to second cutting edge portion 2. Third flank face region 33 is contiguous to third cutting edge portion 3. Fourth flank face region 34 is contiguous to fourth cutting edge portion 4.

[0060] Fifth flank face region 35 is connected to first connection cutting edge portion 11. Sixth flank face region 36 is contiguous to second connection cutting edge portion 12. Seventh flank face region 37 is contiguous to third connection cutting edge portion 13. Each of first flank face region 31, second flank face region 32, third flank face region 33, fourth flank face region 34, fifth flank face region 35, sixth flank face region 36, and seventh flank face region 37 is constituted of cutting edge member 6.

[0061] Second flank face portion 40 has a first side surface region 41, a second side surface region 42, a third side surface region 43, a fourth side surface region 44, a fifth side surface region 45, a sixth side surface region 46, and a seventh side surface region 47. First side surface region 41 is contiguous to each of first flank face region 31 and bottom surface 60. Second side surface region 42 is contiguous to each of second flank face region 32 and bottom surface 60. Third side surface region 43 is contiguous to each of third flank face region 33 and bottom surface 60. Fourth side surface region 44 is contiguous to each of fourth flank face region 34 and bottom surface 60.

[0062] Fifth side surface region 45 is contiguous to each of fifth flank face region 35 and bottom surface 60. Sixth side surface region 46 is contiguous to each of sixth flank face region 36 and bottom surface 60. Seventh side surface region 47 is contiguous to each of seventh flank face region 37 and bottom surface 60. Each of first side surface region 41, second side surface region 42, third side surface region 43, fourth side surface region 44, fifth side surface region 45, sixth side surface region 46, and seventh side surface region 47 is constituted of base metal 7.

[0063] FIG. 4 is a schematic cross sectional view along a line IV-IV of FIG. 2. The cross section shown in FIG. 4 extends through the midpoint of each of two first cutting edge portions 1. A straight line extending through the midpoint of each of two first cutting edge portions 1 is a

diagonal line of cutting insert **100**. As shown in FIG. **4**, through hole **5** extends through base metal **7**. Through hole **5** is opened in each of rake face **50** and bottom surface **60**. Flank face **70** may be inclined perpendicularly to rake face **50**. Specifically, each of first flank face portion **30** and second flank face portion **40** may be inclined perpendicularly to rake face **50**.

#### Second Embodiment

[0064] Next, a configuration of a cutting insert **100** according to a second embodiment will be described. Cutting insert **100** according to the second embodiment is different from cutting insert **100** according to the first embodiment mainly in terms of a configuration in which the flank angle of first flank face portion **30** is  $3^\circ$  or more and  $20^\circ$  or less, and the other configurations are substantially the same as those of cutting insert **100** according to the first embodiment. Hereinafter, the configuration different from that of cutting insert **100** according to the first embodiment will be mainly described.

[0065] FIG. **5** is a schematic perspective view showing a configuration of a cutting insert according to a second embodiment. As shown in FIG. **5**, flank face **70** has holder restraint surface **71**, first flank face portion **30**, and second flank face portion **40**. Second flank face portion **40** is contiguous to holder restraint surface **71**. First flank face portion **30** is inclined inward with respect to the plane perpendicular to rake face **50**. Second flank face portion **40** is inclined with respect to holder restraint surface **71**. Second flank face portion **40** is constituted of the base metal. Second flank face portion **40** is contiguous to each of first flank face portion **30** and bottom surface **60**.

[0066] FIG. **6** is a schematic plan view showing the configuration of the cutting insert according to the second embodiment. FIG. **7** is a schematic cross sectional view along a line VII-VII of FIG. **6**. The cross section shown in FIG. **7** extends through the midpoint of each of two first cutting edge portions **1**.

[0067] As shown in FIG. **7**, the flank angle (first flank angle  $\theta_1$ ) of first cutting edge portion **1** is an inclination angle of first flank face region **31** with respect to the plane perpendicular to rake face **50**. First flank angle  $\theta_1$  may be, for example,  $3^\circ$  or more and  $20^\circ$  or less,  $5^\circ$  or more and  $18^\circ$  or less, or  $7^\circ$  or more and  $15^\circ$  or less.

[0068] FIG. **8** is a schematic cross sectional view along a line VIII-VIII of FIG. **6**. The cross section shown in FIG. **8** intersects each of two fourth cutting edge portions **4** and is perpendicular to the diagonal line of the cutting insert. As shown in FIG. **8**, fourth flank face region **34** is inclined inward with respect to the plane perpendicular to rake face **50**. The flank angle (fourth flank angle  $\theta_4$ ) of fourth cutting edge portion **4** is an inclination angle of fourth flank face region **34** with respect to the plane perpendicular to rake face **50**. Fourth flank angle  $\theta_4$  may be, for example,  $3^\circ$  or more and  $20^\circ$  or less,  $5^\circ$  or more and  $18^\circ$  or less, or  $7^\circ$  or more and  $15^\circ$  or less.

[0069] FIG. **9** is a schematic cross sectional view along a line IX-IX of FIG. **6**. The cross section shown in FIG. **9** intersects each of two second cutting edge portions **2** and is perpendicular to the diagonal line of the cutting insert. As shown in FIG. **9**, second flank face region **32** is inclined inward with respect to the plane perpendicular to rake face **50**. The flank angle (second flank angle  $\theta_2$ ) of second cutting edge portion **2** is an inclination angle of second flank face region **32** with respect to the plane perpendicular to rake face **50**. Second flank angle  $\theta_2$  may be, for example,  $3^\circ$  or more and  $20^\circ$  or less,  $5^\circ$  or more and  $18^\circ$  or less, or  $7^\circ$  or more and  $15^\circ$  or less.

[0070] FIG. **10** is a schematic cross sectional view along a line X-X of FIG. **6**. The cross section shown in FIG. **10** intersects each of two third cutting edge portions **3** and is perpendicular to the diagonal line of the cutting insert. As shown in FIG. **10**, third flank face region **33** is inclined inward with respect to the plane perpendicular to rake face **50**. The flank angle (third flank angle  $\theta_3$ ) of third cutting edge portion **3** is an inclination angle of third flank face region **33** with respect to the plane perpendicular to rake face **50**. Third flank angle  $\theta_3$  may be, for example,  $3^\circ$  or more and  $20^\circ$  or less,  $5^\circ$  or more and  $18^\circ$  or less, or  $7^\circ$  or more and  $15^\circ$  or less.

[0071] FIG. **11** is a schematic cross sectional view along a line XI-XI of FIG. **6**. The cross section shown in FIG. **11** intersects each of first ridgeline portion **21** and second ridgeline portion **22** and is



perpendicular to the diagonal line of the cutting insert. As shown in FIG. 11, holder restraint surface **71** is perpendicular to rake face **50**. The flank angle of holder restraint surface **71** is an inclination angle of holder restraint surface **71** with respect to the plane perpendicular to rake face **50**. The flank angle of holder restraint surface **71** is, for example,  $0^\circ$ .

[0072] Next, a processing method according to the present embodiment will be described. In the processing method according to the present embodiment, a workpiece is processed using cutting insert **100** according to the present embodiment.

[0073] FIG. 12 is a schematic diagram showing a first processing method according to the present embodiment. As shown in FIG. 12, cutting insert **100** is attached to a holder **150** using a retention member **160**. Retention member **160** has a main body portion **162** and an insertion portion **161**. Insertion portion **161** is inserted into through hole **5** of cutting insert **100**. An attachment hole **163** is formed in main body portion **162**. A fastening screw **170** is inserted in attachment hole **163**. Thus, retention member **160** is fixed to holder **150**. Retention member **160** draws cutting insert **100** toward holder **150**, thereby fixing cutting insert **100** to holder **150**.

[0074] Cutting insert **100** according to the present embodiment can perform outer-diameter pulling processing. A workpiece **200** has an outer peripheral surface **201**. The pulling processing is processing performed while moving cutting insert **100** in a first feed direction A. First feed direction A is a direction from cutting insert **100** toward holder **150**. In the pulling processing, workpiece **200** is processed using cutting edge **10**. First feed direction A is parallel to rotation axis X of workpiece **200**. Workpiece **200** is rotated about rotation axis X in a rotation direction R.

[0075] FIG. 13 is an enlarged schematic diagram showing a processing state. The enlarged schematic diagram shown in FIG. 13 shows a state when viewed along the straight line perpendicular to rake face **50**. Cutting edge **10** cuts into workpiece **200** by a cut-in amount  $ap$ .

[0076] As shown in FIG. 13, in the pulling processing, the lateral cutting edge angle of second cutting edge portion **2** is a fifth angle  $\theta_5$ . Fifth angle  $\theta_5$  is an angle formed by a line tangential to cutting edge **10** at a contact point between outer peripheral surface **201** of workpiece **200** and cutting edge **10** and a straight line perpendicular to rotation axis X of workpiece **200**.

[0077] FIG. 14 is a schematic diagram showing a relation between a cut-in amount and a lateral cutting edge angle of the cutting edge. As shown in FIG. 14, the lateral cutting edge angle of second cutting edge portion **2** is changed as the cut-in amount into workpiece **200** is changed. Specifically, the lateral cutting edge angle of second cutting edge portion **2** is monotonously decreased as the cut-in amount into workpiece **200** is increased.

[0078] In the pulling processing for processing workpiece **200** using second cutting edge portion **2**, the lateral cutting edge angle of second cutting edge portion **2** is less than  $90^\circ$ . In the pulling processing for processing workpiece **200** using second cutting edge portion **2**, the lateral cutting edge angle of second cutting edge portion **2** may be  $70^\circ$  or more and  $89^\circ$  or less, or may be  $73^\circ$  or more and  $86^\circ$  or less.

[0079] Second cutting edge portion **2** is used in low cut-in pulling processing. Specifically, the cut-in amount of second cutting edge portion **2** is, for example,  $0.15\text{ mm}$  or less. The cut-in amount of second cutting edge portion **2** may be, for example,  $0.1\text{ mm}$  or less, or  $0.05\text{ mm}$  or less. From another viewpoint, it can be said that second cutting edge portion **2** may be located within a range of  $0.15\text{ mm}$  or less from a position closest to workpiece **200** in the direction perpendicular to the rotation axis.

[0080] As shown in FIG. 14, when the cut-in amount into workpiece **200** is changed, the lateral cutting edge angle of third cutting edge portion **3** is not changed. Specifically, when the cut-in amount into workpiece **200** is increased, the lateral cutting edge angle of third cutting edge portion **3** is unchanged. For example, when the cut-in amount is in a range of  $0.05\text{ mm}$  or more and  $0.5\text{ mm}$  or less, the lateral cutting edge angle of third cutting edge portion **3** may be unchanged.

[0081] The lateral cutting edge angle of third cutting edge portion **3** is, for example,  $60^\circ$  or more and  $85^\circ$  or less. The lateral cutting edge angle of third cutting edge portion **3** may be, for example,

63° or more and 82° or less, or may be 65° or more and 80° or less. As shown in FIG. 14, the minimum value of the lateral cutting edge angle of second cutting edge portion 2 is the same as the lateral cutting edge angle of third cutting edge portion 3.

[0082] Third cutting edge portion 3 is used in high cut-in pulling processing. Specifically, the cut-in amount of third cutting edge portion 3 is, for example, 0.05 mm or more. The cut-in amount of third cutting edge portion 3 may be, for example, 0.1 mm or more, or more than 0.15 mm. The cut-in amount of third cutting edge portion 3 may be 0.5 mm or less. From another viewpoint, it can be said that third cutting edge portion 3 may be located within a range of 0.05 mm or more and 0.5 mm or less from the position closest to workpiece 200 in the direction perpendicular to the rotation axis.

[0083] FIG. 15 is a schematic side view showing the lateral rake angle of the cutting edge. The schematic side view shown in FIG. 15 shows a state when viewed along the straight line perpendicular to rotation axis X of workpiece 200.

[0084] In the pulling processing for processing workpiece 200 using second cutting edge portion 2, cutting insert 100 is fed in first feed direction A along a direction parallel to rotation axis X of workpiece 200.

[0085] As shown in FIG. 15, when viewed in the direction perpendicular to rotation axis X of workpiece 200, the lateral rake angle of second cutting edge portion 2 is an inclination angle of second cutting edge portion 2 with respect to a straight line C1 parallel to rotation axis X of workpiece 200. The lateral rake angle of second cutting edge portion 2 is a sixth angle  $\theta_6$ . Sixth angle  $\theta_6$  may be, for example,  $-20^\circ$  or more and  $20^\circ$  or less. Sixth angle  $\theta_6$  may be  $-15^\circ$  or more and  $15^\circ$  or less, or may be  $-10^\circ$  or more and  $10^\circ$  or less.

[0086] In the pulling processing for processing workpiece 200 using third cutting edge portion 3, cutting insert 100 is fed in first feed direction A along a direction parallel to rotation axis X of workpiece 200.

[0087] As shown in FIG. 15, when viewed in the direction perpendicular to rotation axis X of workpiece 200, the lateral rake angle of third cutting edge portion 3 is an inclination angle of third cutting edge portion 3 with respect to a straight line C2 parallel to rotation axis X of workpiece 200. The lateral rake angle of third cutting edge portion 3 is a seventh angle  $\theta_7$ . Seventh angle  $\theta_7$  may be, for example,  $-20^\circ$  or more and  $20^\circ$  or less. Seventh angle  $\theta_7$  may be  $-15^\circ$  or more and  $15^\circ$  or less, or may be  $-10^\circ$  or more and  $10^\circ$  or less.

[0088] It should be noted that when cutting edge 10 advances before rake face 50 during cutting, the lateral rake angle is a positive angle. On the other hand, when cutting edge 10 advances after rake face 50 during cutting, the lateral rake angle is a negative angle.

[0089] FIG. 16 is a schematic diagram showing a second processing method according to the present embodiment. As shown in FIG. 16, in the second processing method according to the present embodiment, end-surface processing and outer-diameter processing may be performed. A workpiece 200 has an outer peripheral surface 201 and an end surface 202. Outer peripheral surface 201 is parallel to rotation axis X of workpiece 200. End surface 202 is perpendicular to rotation axis X of workpiece 200. Each of pushing processing and corner processing is processing performed while moving cutting insert 100 in a second feed direction B1. In each of the pushing processing and the corner processing, workpiece 200 is processed using first cutting edge portion 1. The pulling processing is processing performed while moving cutting insert 100 in a third feed direction B2.

[0090] In the low cut-in pulling processing, workpiece 200 is processed using second cutting edge portion 2. In the high cut-in pulling processing, workpiece 200 is processed using third cutting edge portion 3. Second feed direction B1 is perpendicular to rotation axis X of workpiece 200. Third feed direction B2 is parallel to rotation axis X of workpiece 200.

[0091] Next, functions and effects of cutting insert 100 and the processing method according to the present embodiment will be described.

[0092] Cutting insert **100** according to the present embodiment has second cutting edge portion **2** for the low cut-in pulling processing and third cutting edge portion **3** for the high cut-in pulling processing. The curvature radius of second cutting edge portion **2** is 3 mm or more. Third cutting edge portion **3** has a straight line shape.

[0093] As the cut-in amount is increased, a load on cutting edge **10** is increased. In the low cut-in pulling processing, the lateral cutting edge angle of second cutting edge portion **2** is decreased as the cut-in amount is increased. By decreasing the lateral cutting edge angle as the load is increased, chipping of cutting edge **10** can be suppressed. On the other hand, when the lateral cutting edge angle is too small, stability in cutting is decreased.

[0094] In cutting insert **100** according to the present embodiment, third cutting edge portion **3** for the high cut-in pulling processing has a straight line shape. Therefore, in the high cut-in pulling processing, the lateral cutting edge angle can be maintained to be unchanged regardless of the cut-in amount. Therefore, it is possible to suppress decreased stability in cutting in the high cut-in pulling processing. Therefore, the life of cutting insert **100** can be long in each of the low cut-in pulling processing and the high cut-in pulling processing.

[0095] Furthermore, since cutting insert **100** according to the present embodiment has fourth cutting edge portion **4** for the finished-surface processing, a finished-surface roughness can be significantly improved. Therefore, an excellent surface roughness can be stably obtained even in high-efficiency processing. It should be noted that the high-efficiency processing is processing in which the volume of workpiece **200** that can be removed per unit time is, for example, 10 cm.sup.3/minute or more.

[0096] In cutting insert **100** according to the present embodiment, the flank angle of each of first cutting edge portion **1**, second cutting edge portion **2**, third cutting edge portion **3**, and fourth cutting edge portion **4** may be 3° or more and 20° or less. Since the flank angle of each of first cutting edge portion **1**, second cutting edge portion **2**, third cutting edge portion **3**, and fourth cutting edge portion **4** is the positive angle, cutting resistance in a thrust component force direction can be reduced. Therefore, dimensional precision can be stably improved.

[0097] In cutting insert **100** according to the present embodiment, flank face **70** may have restraint surface **71** to be restrained by a holder. When the apex angle of second cutting edge portion **2** is defined as first angle  $\theta_8$  and the apex angle of the ridgeline between restraint surface **71** and rake face **50** is defined as second angle  $\theta_9$ , second angle  $\theta_9$  may be smaller than first angle  $\theta_8$ . Thus, restraint force for the cutting insert by the holder can be maintained to be high while increasing the lateral cutting edge angle of second cutting edge portion **2**.

[0098] In cutting insert **100** according to the present embodiment, the flank angle of restraint surface **71** may be 0°. Thus, the restraint force for the cutting insert by the holder can be maintained to be higher.

[0099] In the processing method using the cutting insert according to the present embodiment, in the pulling processing for processing workpiece **200** using second cutting edge portion **2**, the lateral rake angle of second cutting edge portion **2** may be -20° or more and 20° or less. Thus, a load on second cutting edge portion **2** can be reduced. As a result, breakage of second cutting edge portion **2** can be suppressed. Therefore, the life of cutting insert **100** can be further increased.

[0100] In the processing method using the cutting insert according to the present embodiment, in the pulling processing for processing workpiece **200** using third cutting edge portion **3**, the lateral rake angle of third cutting edge portion **3** may be -20° or more and 20° or less. Thus, a load on third cutting edge portion **3** can be reduced. As a result, breakage of third cutting edge portion **3** can be suppressed. Therefore, the life of cutting insert **100** can be further increased.

[0101] In the processing method using the cutting insert according to the present embodiment, second cutting edge portion **2** may be located within the range of 0.15 mm or less from the position closest to workpiece **200** in the direction perpendicular to the rotation axis. In the pulling processing for processing workpiece **200** using second cutting edge portion **2**, the lateral cutting

edge angle of second cutting edge portion 2 may be 70° or more and 89° or less. Thus, a load on second cutting edge portion 2 can be reduced. As a result, breakage of second cutting edge portion 2 can be suppressed. Therefore, the life of cutting insert 100 can be further increased in the low cut-in pulling processing.

[0102] In the processing method using the cutting insert according to the present embodiment, third cutting edge portion 3 may be located within the range of 0.05 mm or more and 0.5 mm or less from the position closest to workpiece 200 in the direction perpendicular to the rotation axis. The lateral cutting edge angle of third cutting edge portion 3 may be 60° or more and 85° or less. Thus, a load on third cutting edge portion 3 can be reduced. As a result, breakage of third cutting edge portion 3 can be suppressed. Therefore, the life of cutting insert 100 can be further increased in the high cut-in pulling processing.

## EXAMPLES

[0103] The present embodiment will be described more specifically with reference to examples. It should be noted that the present embodiment is not limited by these examples.

### Example 1: Low Cut-In Processing Conditions

[0104] Each of cutting inserts 100 (samples SA1 to SA35 and SB1 to SB9) having shapes shown in Tables 1 and 2 was produced experimentally and was evaluated in terms of cutting under the following conditions. Each of cutting inserts 100 of samples SA1 to SA35 and SB1 to SB9 has cutting edge member 6 and base metal 7 (see FIG. 1). In each of cutting inserts 100 of samples SA1 to SA35 and SB1 to SB9, the material of cutting edge member 6 was a cBN-based sintered material.

[0105] In each of Tables 1 and 2, a first cutting edge, a second cutting edge, a third cutting edge, a fourth cutting edge, a first connection portion, a second connection portion, and a third connection portion correspond to first cutting edge portion 1, second cutting edge portion 2, third cutting edge portion 3, fourth cutting edge portion 4, first connection cutting edge portion 11, second connection cutting edge portion 12, and third connection cutting edge portion 13, respectively. In each of Tables 1 and 2, a numerical value described in each of respective columns of the first cutting edge, the second cutting edge, the fourth cutting edge, the first connection portion, the second connection portion, and the third connection portion indicates the curvature radius of a corresponding portion.

TABLE-US-00001

TABLE 1	Item	Flank Angle	Apex Flank	First First	Fourth	Second	Second	Third
Third of Each of	Angle of	Angle of	Cutting	Connection	Cutting	Connection	Cutting	Connection
Cutting First to Fourth	Restraint	Restraint	Edge Portion	Edge Portion	Edge Portion	Edge Portion	Edge	Cutting
Edges Surface	Surface	Unit	mm	mm	mm	mm	mm	mm
SA1	0.8	0.8	20	0.8	7	0.8	7	0.8
SA2	0.1	0.8	20	0.8	7	0.8	7	0.8
SA3	2.4	0.8	20	0.8	7	0.8	7	0.8
SA4	0.8	0.8	20	0.8	3	0.8	7	0.8
SA5	0.8	0.8	20	0.8	13	0.8	7	0.8
SA6	0.8	0.8	20	0.8	20	0.8	7	0.8
SA7	0.8	0.8	20	0.8	3	0.8	7	0.8
SA8	0.8	0.8	20	0.8	13	0.8	7	0.8
SA9	0.8	0.8	20	0.8	7	0.8	7	0.8
SA10	0.8	0.2	20	0.2	7	0.8	7	0.8
SA11	0.8	0.19	20	0.19	7	0.19	7	0.19
SA12	0.8	0.8	20	0.8	7	0.8	7	0.8
SA13	0.8	0.8	20	0.8	7	7	7	7
SA14	0.8	0.8	20	20	7	7	7	7
SA15	0.8	0.8	20	0.8	7	0.8	7	0.8
SA16	0.8	0.8	20	0.8	7	0.8	7	0.8
SA17	0.8	0.8	20	0.8	7	0.8	7	0.8
SA18	0.8	0.8	20	0.8	7	0.8	7	0.8
SA19	0.8	0.8	20	0.8	7	0.8	7	0.8
SA20	0.8	0.8	20	0.8	7	0.8	7	0.8
SA21	0.8	0.8	20	0.8	7	0.8	7	0.8
SA22	0.8	0.8	20	0.8	7	0.8	7	0.8
SA23	0.8	0.8	20	0.8	7	0.8	7	0.8
SA24	0.8	0.8	20	0.8	7	0.8	7	0.8
SA25	0.8	0.8	20	0.8	7	0.8	7	0.8

TABLE-US-00002

TABLE 2	Item	Flank Angle	Apex Flank	First First	Fourth	Second	Second	Third
Third of Each of	Angle of	Angle of	Cutting	Connection	Cutting	Connection	Cutting	Connection
Cutting First to Fourth	Restraint	Restraint	Edge Portion	Edge Portion	Edge Portion	Edge Portion	Edge	Cutting
Edges Surface	Surface	Unit	mm	mm	mm	mm	mm	mm
SA26	0.8	0.8	20	0.8	7	0.8	7	0.8
SA27	0.8	0.8	20	0.8	7	0.8	7	0.8
SA28	0.8	0.8	20	0.8	7	0.8	7	0.8

Line SA29 0.8 0.8 20 0.8 7 0.8 Straight 0 55 0 Line SA30 0.8 0.8 20 0.8 7 0.8 Straight 0 55 0 Line SA31 0.8 0.8 20 0.8 7 0.8 Straight 0 55 0 Line SA32 0.8 0.8 20 0.8 7 0.8 Straight 0 55 0 Line SA33 0.8 0.8 20 0.8 7 0.8 Straight 0 55 0 Line SA34 0.8 0.8 20 0.8 7 0.8 Straight 0 55 0 Line SA35 0.8 0.8 20 0.8 7 0.8 Straight 0 55 0 Line SB1 0.09 0.8 20 0.8 7 0.8 Straight 0 55 0 Line SB2 2.5 0.8 20 0.8 7 0.8 Straight 0 55 0 Line SB3 0.8 0.8 20 0.8 2.9 0.8 Straight 0 55 0 Line SB4 0.8 0.8 20 0.8 7 0.8 R30 0 55 0 SB5 0.8 Straight 20 0.8 7 0.8 Straight 0 55 0 Line Line SB6 0.8 0.8 20 Straight 7 0.8 Straight 0 55 0 Line Line SB7 0.8 0.8 20 0.8 7 Straight Straight 0 55 0 Line Line SB8 0.8 0.2 20 0.2 Straight — — 0 80 0 Line SB9 0.8 0.2 20 0.2 3 — — 0 80 0

[0106] Cutting inserts **100** of samples SA1 to SA35 are examples of the present disclosure. In each of cutting inserts **100** of samples SA1 to SA35, the curvature radius of first culling edge portion **1** was 0.1 mm or more and 2.4 mm or less. Fourth cutting edge portion **4** had a curved shape having a curvature radius of 3 mm or more. Second culling edge portion **2** had a curved shape having a curvature radius of 3 mm or more. Third cutting edge portion **3** had a straight line shape. Each of first connection cutting edge portion **11**, second connection cutting edge portion **12**, and third connection culling edge portion **13** had a curved shape.

[0107] Cutting inserts **100** of samples SB1 to SB9 are comparative examples. In cutting insert **100** of sample SB1, the curvature radius of first cutting edge portion **1** was 0.09 mm. In cutting insert **100** of sample SB2, the curvature radius of first cutting edge portion **1** was 2.5 mm. In cutting insert **100** of sample SB3, the curvature radius of second cutting edge portion **2** was 2.9 mm. In cutting insert **100** of sample SB4, third cutting edge portion **3** has a curved shape with a curvature radius of 30 mm.

[0108] In cutting insert **100** of sample SB5, first connection cutting edge portion **11** had a straight line shape. In cutting insert **100** of sample SB6, second connection cutting edge portion **12** had a straight line shape. In cutting insert **100** of sample SB7, third connection cutting edge portion **13** had a straight line shape. In cutting insert **100** of sample SB8, second cutting edge portion **2** had a straight line shape, and third connection cutting edge portion **13** and third cutting edge portion **3** were not formed. In cutting insert **100** of sample SB9, third connection cutting edge portion **13** and third cutting edge portion **3** were not formed.

[0109] A workpiece **200** below was processed under the following cutting conditions with cutting insert **100** being attached to holder **150**. A cutting time (tool life) when cutting edge **10** of cutting insert **100** was broken was evaluated.

(Cutting Geometry)

[0110] Cutting edge inclination angle= $-5^{\circ}$

(Workpiece)

[0111] High-hardness steel SCM415 (HRC60); diameter=85 mm; length=200 mm

(Cutting Conditions)

[0112] Cutting rate:  $V=250$  m/min; feed rate:  $f=0.5$  mm/rev.; cut-in amount:  $a_p=0.05$  mm; wet type (Manner of Processing)

[0113] Outer-diameter processing (pulling processing)

[0114] Results are collectively shown in Tables 3 and 4. As shown in Tables 3 and 4, the lateral rake angle of cutting edge **10** was  $-21^{\circ}$  or more and  $21^{\circ}$  or less. The lateral cutting edge angle of second cutting edge portion **2** was  $69^{\circ}$  or more and  $89^{\circ}$  or less. Only in cutting insert **100** of sample SA35, the lateral cutting edge angle of third cutting edge portion **3** was  $80^{\circ}$ .

TABLE-US-00003 TABLE 3 Item Lateral Lateral Lateral Cutting Edge Position Cutting Edge Position Rake Angle of Second of Second Angle of Third of Third Tool Angle Cutting Edge Cutting Edge Cutting Edge Life Unit  $^{\circ}$   $^{\circ}$  mm  $^{\circ}$  mm km SA1  $-5$  83 0.15 — 0.5 8.3 SA2  $-5$  83 0.15 — 0.5 5.4 SA3  $-5$  83 0.15 — 0.5 5.5 SA4  $-5$  80 0.15 — 0.5 5.2 SA5  $-5$  85 0.15 — 0.5 8.5 SA6  $-5$  86 0.15 — 0.5 8.8 SA7  $-5$  83 0.15 — 0.5 5.4 SA8  $-5$  83 0.15 — 0.5 8.6 SA9  $-5$  83 0.15 — 0.5 8.2 SA10  $-5$  83 0.15 — 0.5 6 SA11  $-5$  83 0.15 — 0.5 5.5 SA12  $-5$  83 0.15 — 0.5 7.3 SA13  $-5$  83 0.15 — 0.5 5.2 SA14  $-5$  83 0.15 — 0.5 8.8 SA15  $-5$  83 0.15 — 0.5 6.3 SA16  $-5$



cutting edge portion **12**, and third connection cutting edge portion **13**, respectively. In each of Tables 5 and 6, a numerical value described in each of respective columns of the first cutting edge, the second cutting edge, the fourth cutting edge, the first connection portion, the second connection portion, and the third connection portion indicates the curvature radius of a corresponding portion.

TABLE-US-00005

Item	Flank	Angle of First	Angle of Second	Angle of Third	Angle of Fourth	Angle of Cutting	Connection	Restraint	Restraint	Edge Portion	Edge Portion	Edge Portion	
Cutting	Connection	Cutting	Cutting	Restraint	Restraint	Edge Portion	Edge Portion	Edge Portion	Edge Portion	Edge Portion	Edge Portion	Edge Portion	
Edge	Edges	Surface	Surface	Unit	mm	mm	mm	mm	mm	mm	mm	mm	
—	°	°	°	°	°	°	°	°	°	°	°	°	
SC1	0.8	0.8	20	0.8	7	0.8	0.8	0.8	20	0.8	7	0.8	
Straight	0	55	0	Line	SC2	0.1	0.8	20	0.8	7	0.8	Straight	
0	55	0	Line	SC4	0.8	0.8	20	0.8	3	0.8	Straight	0	
55	0	Line	SC5	0.8	0.8	20	0.8	13	0.8	Straight	0	55	
0	55	0	Line	SC6	0.8	0.8	20	0.8	20	0.8	Straight	0	55
0	55	0	Line	SC7	0.8	0.8	3	0.8	7	0.8	Straight	0	55
0	55	0	Line	SC8	0.8	0.8	13	0.8	7	0.8	Straight	0	55
0	55	0	Line	SC9	0.8	0.8	20	0.8	7	0.8	Straight	0	55
0	55	0	Line	SC10	0.8	0.2	20	0.2	7	0.8	Straight	0	55
0	55	0	Line	SC11	0.8	0.19	20	0.19	7	0.19	Straight	0	55
0	55	0	Line	SC12	0.8	0.8	20	20	7	0.8	Straight	0	55
0	55	0	Line	SC13	0.8	0.8	20	0.8	7	7	Straight	0	55
0	55	0	Line	SC14	0.8	0.8	20	20	7	7	Straight	0	55
0	55	0	Line	SC15	0.8	0.8	20	0.8	7	0.8	Straight	2	55
0	55	0	Line	SC16	0.8	0.8	20	0.8	7	0.8	Straight	2	55
0	55	0	Line	SC17	0.8	0.8	20	0.8	7	0.8	Straight	20	55
0	55	0	Line	SC18	0.8	0.8	20	0.8	7	0.8	Straight	20	55
0	55	0	Line	SC19	0.8	0.8	20	0.8	7	0.8	Straight	0	30
0	55	0	Line	SC20	0.8	0.8	20	0.8	7	0.8	Straight	0	30
0	55	0	Line	SC21	0.8	0.8	20	0.8	7	0.8	Straight	0	80
0	55	0	Line	SC22	0.8	0.8	20	0.8	7	0.8	Straight	0	80
0	55	0	Line	SC23	0.8	0.8	20	0.8	7	0.8	Straight	5	55
0	55	0	Line	SC24	0.8	0.8	20	0.8	7	0.8	Straight	5	55
0	55	0	Line	SC25	0.8	0.8	20	0.8	7	0.8	Straight	11	55
0	55	0	Line	SC26	0.8	0.8	20	0.8	7	0.8	Straight	11	55

TABLE-US-00006

Item	Flank	Angle of First	Angle of Second	Angle of Third	Angle of Fourth	Angle of Cutting	Connection	Restraint	Restraint	Edge Portion	Edge Portion	Edge Portion	
Cutting	Connection	Cutting	Cutting	Restraint	Restraint	Edge Portion	Edge Portion	Edge Portion	Edge Portion	Edge Portion	Edge Portion	Edge Portion	
Edge	Edges	Surface	Surface	Unit	mm	mm	mm	mm	mm	mm	mm	mm	
—	°	°	°	°	°	°	°	°	°	°	°	°	
SC26	0.8	0.8	20	0.8	7	0.8	0.8	0.8	20	0.8	7	0.8	
Straight	0	55	0	Line	SC27	0.8	0.8	20	0.8	7	0.8	Straight	
0	55	0	Line	SC28	0.8	0.8	20	0.8	7	0.8	Straight	0	
55	0	Line	SC29	0.8	0.8	20	0.8	7	0.8	Straight	0	55	
0	55	0	Line	SC30	0.8	0.8	20	0.8	7	0.8	Straight	0	55
0	55	0	Line	SC31	0.8	0.8	20	0.8	7	0.8	Straight	0	55
0	55	0	Line	SC32	0.8	0.8	20	0.8	7	0.8	Straight	0	55
0	55	0	Line	SC33	0.8	0.8	20	0.8	7	0.8	Straight	0	55
0	55	0	Line	SC34	0.8	0.8	20	0.8	7	0.8	Straight	0	55
0	55	0	Line	SC35	0.8	0.8	20	0.8	7	0.8	Straight	0	55
0	55	0	Line	SC36	0.8	0.8	20	0.8	7	0.8	Straight	0	55
0	55	0	Line	SD1	0.09	0.8	20	0.8	7	0.8	Straight	0	55
0	55	0	Line	SD2	2.5	0.8	20	0.8	7	0.8	Straight	0	55
0	55	0	Line	SD3	0.8	0.8	20	0.8	2.9	0.8	Straight	0	55
0	55	0	Line	SD4	0.8	0.8	20	0.8	7	0.8	R30	0	
55	0	SD5	0.8	Straight	20	0.8	7	0.8	Straight	0	55	0	
55	0	Line	SD6	0.8	0.8	20	Straight	7	0.8	Straight	0	55	
0	55	0	Line	SD7	0.8	0.8	20	0.8	7	Straight	0	55	
0	55	0	Line	SD8	0.8	0.2	20	0.2	3	—	—	0	
0	55	0	Line	SD9	0.8	0.2	20	0.2	3	—	—	0	

[0126] Cutting inserts **100** of samples SC1 to SC36 are examples of the present disclosure. In each of cutting inserts **100** of samples SC1 to SC36, the curvature radius of first cutting edge portion **1** was 0.1 mm or more and 2.4 mm or less. Fourth cutting edge portion **4** had a curved shape having a curvature radius of 3 mm or more. Second cutting edge portion **2** had a curved shape having a curvature radius of 3 mm or more. Third cutting edge portion **3** had a straight line shape. Each of first connection cutting edge portion **11**, second connection cutting edge portion **12**, and third connection cutting edge portion **13** had a curved shape.

[0127] Cutting inserts **100** of samples SD1 to SD9 are comparative examples. In cutting insert **100** of sample SD1, the curvature radius of first cutting edge portion **1** was 0.09 mm. In cutting insert **100** of sample SD2, the curvature radius of first cutting edge portion **1** was 2.5 mm. In cutting insert **100** of sample SD3, the curvature radius of second cutting edge portion **2** was 2.9 mm. In cutting insert **100** of sample SD4, third cutting edge portion **3** had a curved shape having a curvature radius of 30 mm.

[0128] In cutting insert **100** of sample SD5, first connection cutting edge portion **11** had a straight line shape. In cutting insert **100** of sample SD6, second connection cutting edge portion **12** had a straight line shape. In cutting insert **100** of sample SD7, third connection cutting edge portion **13**





cutting insert **100** has a long tool life when the flank angle of each of first cutting edge portion **1**, second cutting edge portion **2**, third cutting edge portion **3**, and fourth cutting edge portion **4** is  $20^{\circ}$  or less.

[0140] As indicated by each of cutting inserts **100** of samples SC19 to SC22, it was confirmed that cutting insert **100** has a long tool life when the apex angle of holder restraint surface **71** is  $30^{\circ}$  or more and  $80^{\circ}$  or less.

[0141] As indicated by each of cutting inserts **100** of samples SC23 to SC25, it was confirmed that cutting insert **100** has a long tool life when the flank angle of holder restraint surface **71** is  $11^{\circ}$  or less.

[0142] As indicated by each of cutting inserts **100** of samples SC26 to SC29, it was confirmed that cutting insert **100** has a long tool life when the lateral rake angle of cutting edge **10** is  $-20^{\circ}$  or more and  $20^{\circ}$  or less.

[0143] As indicated by each of cutting inserts **100** of samples SC32 to SC35, it was confirmed that cutting insert **100** has a long tool life when the lateral cutting edge angle of third cutting edge portion **3** is  $60^{\circ}$  or more and  $86^{\circ}$  or less.

[0144] It should be noted that each of cutting inserts **100** of samples SB8 and SD8 had a long tool life under the high cut-in processing conditions, but did not have a long tool life under the low cut-in processing conditions. Each of cutting inserts **100** of samples SB9 and SD9 had a long tool life under the low cut-in processing conditions, but did not have a long tool life under the high cut-in processing conditions.

[0145] In view of the above results, it was proved that the tool life is long under both the low cut-in processing conditions and the high cut-in processing conditions when the curvature radius of first cutting edge portion **1** is 0.1 mm or more and 2.4 mm or less, fourth cutting edge portion **4** has a curved shape having a curvature radius of 3 mm or more, second cutting edge portion **2** has a curved shape having a curvature radius of 3 mm or more, and third cutting edge portion **3** has a straight line shape.

[0146] The embodiments and examples disclosed herein are illustrative and non-restrictive in any respect. The scope of the present invention is defined by the terms of the claims, rather than the embodiments described above, and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

#### REFERENCE SIGNS LIST

[0147] **1** first cutting edge portion; **2** second cutting edge portion; **3** third cutting edge portion; **4** fourth cutting edge portion; **5** through hole; **6** cutting edge member; **7** base metal; **8** counterbore portion; **10** cutting edge; **11** first connection cutting edge portion; **12** second connection cutting edge portion; **13** third connection cutting edge portion; **20** ridgeline; **21** first ridgeline portion; **22** second ridgeline portion; **30** first flank face portion; **31** first flank face region; **32** second flank face region; **33** third flank face region; **34** fourth flank face region; **35** fifth flank face region; **36** sixth flank face region; **37** seventh flank face region; **40** second flank face portion; **41** first side surface region; **42** second side surface region; **43** third side surface region; **44** fourth side surface region; **45** fifth side surface region; **46** sixth side surface region; **47** seventh side surface region; **50** rake face; **51** first rake face region; **52** second rake face region; **60** bottom surface; **70** flank face; **71** holder restraint surface (restraint surface); **100** cutting insert; **150** holder; **160** retention member; **161** insertion portion; **162** main body portion, **163** attachment hole; **170** fastening screw; **200** workpiece; **201** outer peripheral surface; **202** end surface; A first feed direction; B1 second feed direction; B2 third feed direction; C1, C2 straight line; R rotation direction; X rotation axis; ap cut-in amount.

## Claims

1. A cutting insert having a surface involved in cutting, the surface being composed of a cBN-based sintered material, a diamond-based sintered material, a ceramic, a cermet, or a cemented carbide, the cutting insert comprising: a rake face; a flank face; and a cutting edge constituted of a ridgeline between the rake face and the flank face, wherein the cutting edge has a first cutting edge portion for corner processing, a second cutting edge portion for low cut-in pulling processing, a third cutting edge portion for high cut-in pulling processing, a fourth cutting edge portion for finished-surface processing, a first connection cutting edge portion that connects the first cutting edge portion and the fourth cutting edge portion, a second connection cutting edge portion that connects the second cutting edge portion and the fourth cutting edge portion, and a third connection cutting edge portion that connects the second cutting edge portion and the third cutting edge portion, the fourth cutting edge portion is disposed between the first cutting edge portion and the second cutting edge portion, the second cutting edge portion is disposed between the fourth cutting edge portion and the third cutting edge portion, each of the first cutting edge portion, the second cutting edge portion, and the fourth cutting edge portion has a curved shape, a curvature radius of the first cutting edge portion is 0.1 mm or more and 2.4 mm or less, a curvature radius of the second cutting edge portion is 3 mm or more, a curvature radius of the fourth cutting edge portion is 3 mm or more, the third cutting edge portion has a straight line shape, and each of the first connection cutting edge portion, the second connection cutting edge portion, and the third connection cutting edge portion has a curved shape, a curvature radius of the second cutting edge portion is smaller than a curvature radius of the fourth cutting edge portion.
2. The cutting insert according to claim 1, wherein a curvature radius of each of the first connection cutting edge portion, the second connection cutting edge portion, and the third connection cutting edge portion is 0.2 mm or more.
3. The cutting insert according to claim 1, wherein a flank angle of each of the first cutting edge portion, the second cutting edge portion, the third cutting edge portion, and the fourth cutting edge portion is 3° or more and 20° or less.
4. The cutting insert according to claim 1, wherein the flank face has a restraint surface to be restrained by a holder, and when an apex angle of the second cutting edge portion is defined as a first angle and an apex angle of a ridgeline between the restraint surface and the rake face is defined as a second angle, the second angle is smaller than the first angle, and the second angle is 30° or more and 80° or less.
5. The cutting insert according to claim 1, wherein the flank face has a restraint surface to be restrained by a holder, and when an apex angle of the second cutting edge portion is defined as a first angle and an apex angle of a ridgeline between the restraint surface and the rake face is defined as a second angle, the second angle is smaller than the first angle, and the first angle is 35° or more and 85° or less.
6. The cutting insert according to claim 4, wherein a flank angle of the restraint surface is 0°.
7. A processing method using the cutting insert according to claim 1, wherein in pulling processing for processing a workpiece using the second cutting edge portion, a lateral rake angle of the second cutting edge portion is -20° or more and 20° or less.
8. The processing method according to claim 7, wherein in pulling processing for processing a workpiece using the third cutting edge portion, a lateral rake angle of the third cutting edge portion is -20° or more and 20° or less.
9. The processing method according to claim 7, wherein the second cutting edge portion is located within a range of 0.15 mm or less from a position closest to the workpiece in a direction perpendicular to a rotation axis, and in the pulling processing for processing the workpiece using the second cutting edge portion, a lateral cutting edge angle of the second cutting edge portion is 70° or more and 89° or less.
10. The processing method according to claim 7, wherein the third cutting edge portion is located

within a range of 0.05 mm or more and 0.5 mm or less from a position closest to the workpiece in a direction perpendicular to a rotation axis, and a lateral cutting edge angle of the third cutting edge portion is 60° or more and 85° or less.

**11.** The processing method according to claim 7, wherein a minimum value of a lateral cutting edge angle of the second cutting edge portion is the same as a lateral cutting edge angle of the third cutting edge portion.

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