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(54) **Title:** TRIANGULAR-SHAPED INDEXABLE CUTTING INSERT HAVING RECESSED SIDE SURFACES AND ROTARY CUTTING TOOL

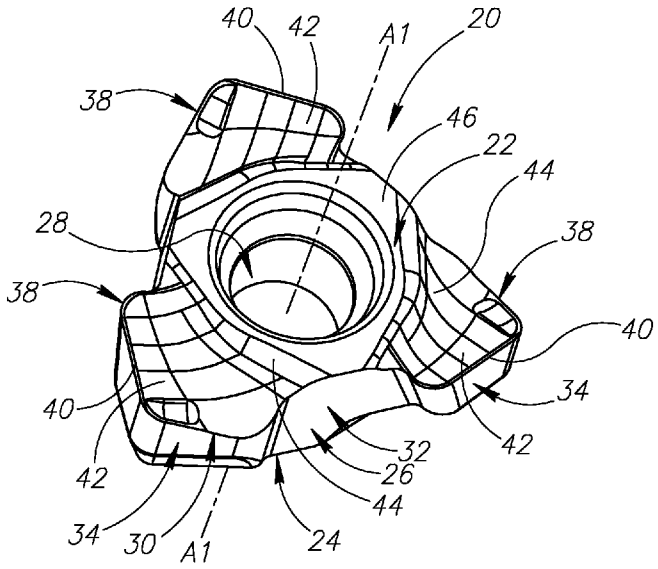

FIG.1

(57) **Abstract:** An indexable cutting insert (20) has opposing upper and lower end surfaces (22, 24), and a peripheral surface (26) including three side surfaces (32) circumferentially alternating with three corner surfaces (34). The three side surfaces define an imaginary triangle and an imaginary hexagon. Each corner surface intersects the upper end surface to form an upper corner peripheral edge (38) having a primary cutting edge (40). In a top view, each triangle side traverses two upper corner peripheral edges, imaginary lines tangential to the end points of each primary cutting edge are either collinear or form an obtuse angle greater than 175 degrees, each primary cutting edge has a primary length greater than half the hexagon side length, and at least one triangle side traverses each primary cutting edge. The insert is removably secured in a rotary cutting tool such that one of the upper corner peripheral edges contains an axially forwardmost point of the insert's upper peripheral edge.

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TRIANGULAR-SHAPED INDEXABLE CUTTING INSERT HAVING RECESSED SIDE SURFACES AND ROTARY CUTTING TOOL

FIELD OF THE INVENTION

The present invention relates to a cutting tool and a triangular shaped indexable cutting insert therefor, for use in metal cutting processes in general, and for milling operations in particular.

BACKGROUND OF THE INVENTION

Within the field of cutting tools used in milling operations, there are some examples of triangular-shaped indexable cutting inserts having recessed side surfaces, removably retained in an insert receiving pocket of a cutting body.

CN 103506680 discloses a triangular shaped indexable cutting insert having opposing upper and lower end surfaces with a peripheral surface extending therebetween, the peripheral surface including three side surfaces and three corner surfaces, each corner surface intersecting an upper end surface to form a curved upper cutting edge, and each side surface having a recessed side surface.

US 2016/0107248 discloses a triangular shaped indexable cutting insert having opposing upper and lower end surfaces with a peripheral surface extending therebetween, the peripheral surface including three side surfaces and three corner surfaces, each corner surface intersecting an upper end surface to form an upper cutting edge. Each upper cutting edge includes a radiused component having a first end and a second end and first and second components at the first and the second ends of the radiused component, respectively, the first and second components being less curved than the radiused component. The lower end surface includes three radially extending mounting grooves, and each side surface includes at least one substantially V-shaped valley formed by first and second support surfaces.

US 2010/0329800 discloses a double-sided indexable cutting insert having three heads spaced apart by an intermediate part, each head including a front portion, both sides of which

have two essentially straight cutting edges converging at a nose edge, and a rear portion which has two side contact surfaces. The intermediate part has three 'recessed' intermediate surfaces, which in a top view or a bottom view of the cutting insert define an imaginary triangle, none of the imaginary sides of which traverse any of the cutting edges.

There is a need in the field to provide an improved triangular-shaped indexable cutting insert having a versatile mounting means.

There is also a need in the field to provide an improved triangular-shaped indexable cutting insert having a compact mounting means.

There is a further need in the field to provide an improved cutting tool suitable for a wide range of milling operations, including ramping operations.

There is yet a further need in the field to provide an improved cutting tool in which the triangular shaped indexable cutting insert is removably secured in a cutting body with a high level of stability.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided an indexable triangular-shaped cutting insert having features designed in an effort to satisfy one or more of the aforementioned needs in the field. The cutting insert, under one aspect of the invention, comprising:

opposing upper and lower surfaces with a peripheral surface extending therebetween and a central axis extending therethrough,

the lower surface having a downward facing planar base surface defined by a first horizontal plane perpendicular to the central axis,

the peripheral surface intersecting the upper surface to form a continuous upper peripheral edge and having three side surfaces circumferentially alternating with three corner surfaces,

each corner surface intersecting the upper surface to form an upper corner peripheral edge, and each upper corner peripheral edge having a primary cutting edge extending from a first end point to a second end point,

wherein in a cross-section taken in a second horizontal plane perpendicular to the central axis and intersecting the three side surfaces, the three side surfaces define three sides of a first imaginary triangle and three non-adjacent sides of a first imaginary hexagon, and

wherein in a top view of the cutting insert:

each side of the first imaginary triangle traverses two upper corner peripheral edges,

first and second imaginary straight lines tangential to each primary cutting edge at its first and second end points, respectively, are either collinear or form an obtuse primary bend angle of greater than 175 degrees,

each primary cutting edge has a primary length between its first and second end points greater than half the hexagon side length of the first imaginary hexagon, and

at least one side of the first imaginary triangle traverses each primary cutting edge.

Also in accordance with the present invention, there is provided a rotary cutting tool rotatable about a tool axis defining a forward-rearward direction, and comprising a cutting body having at least one insert receiving pocket, and at least one cutting insert of the sort described above removably secured in the insert receiving pocket.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding, the invention will now be described, by way of example only, with reference to the accompanying drawings in which chain-dash lines represent cut-off boundaries for partial views of a member and in which:

Fig. 1 is a perspective view of a cutting insert in accordance with a first embodiment of the present invention;

Fig. 2 is a top view of the cutting insert shown in Fig. 1;

Fig. 3 is a side view of the cutting insert shown in Fig. 1;

Fig. 4 is a bottom view of the cutting insert shown in Fig. 1;

Fig. 5 is a cross-sectional view of the cutting insert shown in Fig. 3, taken along the line V-V;

Fig. 6 is a cross-sectional view of the cutting insert shown in Fig. 2, taken along the line VI-VI;

Fig. 7 is a partial cut view of the cutting insert shown in Fig. 2, taken along the line VII-VII;

Fig. 8 is a cross-sectional view of the cutting insert shown in Fig. 3, taken along the line VIII-VIII;

Fig. 9 is a perspective view of a cutting insert in accordance with a second embodiment of the present invention;

Fig. 10 is a top view of the cutting insert shown in Fig. 9;

Fig. 11 is a side view of the cutting insert shown in Fig. 9;

Fig. 12 is a bottom view of the cutting insert shown in Fig. 9;

Fig. 13 is a cross-sectional view of the cutting insert shown in Fig. 11, taken along the line XIII-XIII;

Fig. 14 is a cross-sectional view of the cutting insert shown in Fig. 10, taken along the line XIV-XIV;

Fig. 15 is a partial cut view of the cutting insert shown in Fig. 10, taken along the line XV-XV;

Fig. 16 is a cross-sectional view of the cutting insert shown in Fig. 11, taken along the line XVI-XVI;

Fig. 17 is a perspective view of a cutting tool in accordance with some embodiments of the present invention, with one of its cutting inserts removed;

Fig. 18 is a side view of the cutting tool shown in Fig. 17;

Fig. 19 is a detailed side view of the cutting tool shown in Fig. 17;

Fig. 20 is a front view of an insert receiving pocket of the cutting tool shown in Fig. 17, with its cutting insert removed; and

Fig. 21 is a front view of the insert receiving pocket shown in Fig. 20, with its cutting insert secured.

DETAILED DESCRIPTION OF THE INVENTION

As shown in Figs. 1 to 4 and 9 to 12, a first aspect of the present invention relates to an indexable triangular shaped cutting insert **20**, **120** having opposing upper and lower surfaces **22**, **24** with a peripheral surface **26** extending therebetween and a central axis **A1** extending therethrough.

Figs. 1 to 4 show a first embodiment cutting insert **20** suitable for milling operations at high feed rates.

Figs. 9 to 12 show a second embodiment cutting insert **120** suitable for milling a square shoulder in a workpiece.

It should be appreciated that throughout the description and claims, the same reference numerals have been used for features that are common to both the first and second embodiment cutting inserts **20**, **120**.

In some embodiments of the present invention, the cutting insert **20**, **120** may be indexable about the central axis **A1**.

Also in some embodiments of the present invention, the cutting insert **20**, **120** may exhibit three-fold rotational symmetry about the central axis **A1**.

Further in some embodiments of the present invention, a central bore **28** coaxial with the central axis **A1** may intersect the upper and lower surfaces **22**, **24**.

Yet further in some embodiments of the present invention, the cutting insert **20**, **120** may preferably be manufactured by form pressing and sintering a cemented carbide, such as tungsten carbide, and may be coated or uncoated.

As shown in Figs. 1, 2, 9 and 10, the peripheral surface **26** intersects the upper surface **22** to form a continuous upper peripheral edge **30**, and has three side surfaces **32** circumferentially alternating with three corner surfaces **34**.

In some embodiments of the present invention, each side surface **32** may be planar and parallel to the central axis **A1**.

As shown in Figs. 3 and 11, the lower surface **24** has a downward facing planar base surface **36** defined by a first horizontal plane **PH1** perpendicular to the central axis **A1**.

In some embodiments of the present invention, each side surface **32** may intersect the base surface **36**.

In other embodiments of the present invention (not shown), the base surface **36** may include a plurality of coplanar base sub-surfaces.

As shown in Figs. 1 to 3 and 9 to 11, each corner surface **34** intersects the upper surface **22** to form an upper corner peripheral edge **38**, and each upper corner peripheral edge **38** has a primary cutting edge **40** extending from a first end point **N1** to a second end point **N2**.

In some embodiments of the present invention, each primary cutting edge **40** may slope downwardly from its first end point **N1** to its second end point **N2**.

Also in some embodiments of the present invention, each primary cutting edge **40** may slope continuously downwardly from its first end point **N1** to its second end point **N2**.

Further in some embodiments of the present invention, the lower surface **24** may be devoid of cutting edges, and the cutting insert **20**, **120** may be described a 'single-sided'.

As shown in Figs. 5 and 13, in a cross-section taken in a second horizontal plane **PH2** perpendicular to the central axis **A1** and intersecting the three side surfaces **32**, the three side surfaces **32** define three sides of a first imaginary triangle **T1** and three non-adjacent sides of a first imaginary hexagon **H1**.

Also, as shown in Figs. 5 and 13, the first imaginary triangle **T1** has three imaginary first bisector lines **LB1**, each imaginary first bisector line **LB1** containing one of the first imaginary triangle's three corners and bisecting its non-adjacent (opposite) side.

It should be appreciated that the first imaginary triangle **T1** is an equilateral triangle having its center contained in the central axis **A1**.

It should also be appreciated that the first imaginary hexagon **H1** is a regular hexagon having its center contained in the central axis **A1** and six sides of equal length.

According to the first aspect of the present invention, as shown in Figs. 2 and 10, in a top view of the cutting insert **20**, **120**, each side of the first imaginary triangle **T1** traverses two upper corner peripheral edges **38**.

By virtue of each side of the first imaginary triangle **T1** traversing two upper corner peripheral edges **38**, the three side surfaces **32** are recessed, and thus provide a compact means for mounting the cutting insert **20**, **120**.

In some embodiments of the present invention, as shown in Figs. 2 and 10, in the top view of the cutting insert **20**, **120**, the first imaginary triangle's three corners may be located outside the upper peripheral edge **30**.

Also in some embodiments of the present invention, as shown in Figs. 2 and 10, in the top view of the cutting insert **20**, **120**, each upper corner peripheral edge **38** may be traversed only once by the same side of the first imaginary triangle **T1**.

Further in some embodiments of the present invention, as shown in Figs. 2 and 10, in the top view of the cutting insert **20**, **120**, the first imaginary hexagon's six corners may be located inside the upper peripheral edge **30**.

It should be appreciated that for embodiments of the present invention in which the first imaginary hexagon's six corners are located inside the upper peripheral edge **30**, the length of each upper corner peripheral edge **38** is advantageously increased.

In some embodiments of the present invention, as shown in Figs. 2 and 10, in the top view of the cutting insert **20**, **120**, each imaginary first bisector line **LB1** may intersect one of the upper corner peripheral edges **38**, and each upper corner peripheral edge **38** may not exhibit mirror symmetry about its associated imaginary first bisector line **LB1**.

According to the first aspect of the present invention, as shown in Figs. 2 and 10, in the top view of the cutting insert **20**, **120**, first and second imaginary straight lines **L1**, **L2** tangential to each primary cutting edge **40** at its first and second end points **N1**, **N2**, respectively, are either collinear or form an obtuse primary bend angle $\alpha 1$ of greater than 175 degrees, i.e. $175° < \alpha 1 < 180°$.

For embodiments of the present invention in which the first and second imaginary straight lines **L1**, **L2** are collinear, for example, in the top view of the first embodiment cutting insert **20** as shown in Fig. 2, each primary cutting edge **40** may be straight.

For embodiments of the present invention in which the first and second imaginary straight lines **L1**, **L2** form an obtuse primary bend angle $\alpha 1$ of greater than 175 degrees, for example, in the top view of the second embodiment cutting insert **120** as shown in Fig. 10, each primary cutting edge **40** may be slightly convex.

It should be appreciated that each primary cutting edge **40** may be slightly convex in the top view of the second embodiment cutting insert **120**, such that when the cutting insert **120** is

inclined with respect to the workpiece, the operative primary cutting edge **40** is capable of milling a square shoulder therein.

According to the first aspect of the present invention, as shown in Figs. 2 and 10, in the top view of the cutting insert **20**, **120**, each primary cutting edge **40** has a primary length **LP** between its first and second end points **N1**, **N2** greater than half the hexagon side length **LH** of the first imaginary hexagon **H1**, i.e. **LP** > **LH***1/2, and at least one side of the first imaginary triangle **T1** traverses each primary cutting edge **40**.

In some embodiments of the present invention, as shown in Figs. 2 and 10, in the top view of the cutting insert **20**, **120**, the primary length **LP** may be greater than two-thirds of the hexagon side length **LH**, i.e. **LP** > **LH***2/3.

Also in some embodiments of the present invention, as shown in Figs. 2 and 10, in the top view of the cutting insert **20**, **120**, no portion of the cutting insert **20**, **120** may be located outside the upper peripheral edge **30**.

As shown in Figs. 1, 2, 9 and 10, the upper surface **22** may include a rake surface **42** adjacent each primary cutting edge **40** and a chip deflection surface **44** between each rake surface **42** and a central top surface **46**.

In some embodiments of the present invention, the central top surface **46** may entirely surround the central bore **28**.

Also in some embodiments of the present invention, each chip deflection surface **44** may extend along a circumferential extent **E1** of the top surface **46**.

As shown in Figs. 3 and 11, the top surface **46** may be planar and defined by a third horizontal plane **PH3** perpendicular to the central axis **A1**.

In some embodiments of the present invention, no portion of the cutting insert **20**, **120** may be located upward of the third horizontal plane **PH3**.

Also, as shown in Figs. 3 and 11, a fourth horizontal plane **PH4** perpendicular to the central axis **A1** may intersect each chip deflection surface **44** along its entire circumferential extent **E1**, and not intersect any of the three primary cutting edges **40**.

It should be appreciated that for embodiments of the present invention in which the fourth horizontal plane **PH4** intersects each chip deflection surface **44** and none of the three primary

cutting edges **40**, each chip deflection surface **44** extends upward of its associated primary cutting edge **40**, thus providing greater control of the flow of the chips.

In some embodiments of the present invention, each side surface **32** may intersect the top surface **46**.

As shown in Figs. 6 and 14, in a cross-section taken in a first vertical plane **PV1** containing the central axis **A1** and a mid-point **N3** of one of the primary cutting edges **40**, the rake surface **42** may slope downwardly away from the primary cutting edge **40**, and the chip deflection surface **44** may slope upwardly towards the top surface **46**.

It should be appreciated that in the top view of the cutting insert **20**, **120**, the mid-point **N3** of each primary cutting edge **40** is equidistant from its associated first and second end points **N1**, **N2**.

In some embodiments of the present invention, as shown in Figs. 6 and 14, in the cross-section taken in the first vertical plane **PV1**, a third imaginary straight line **L3** parallel to the central axis **A1** and intersecting the base surface **36** may intersect the rake surface **42** or the chip deflection surface **44**.

As shown in Fig. 6, the third imaginary straight line **L3** of the first embodiment cutting insert **20** intersects the chip deflection surface **44**, and as shown in Fig. 14, the third imaginary straight line **L3** of the second embodiment cutting insert **120** intersects the rake surface **42**.

In some embodiments of the present invention, as shown in Figs. 2 and 10, in the top view of the cutting insert **20**, **120**, each chip deflection surface **44** may be at least partially located inside the first imaginary hexagon **H1**.

It should be appreciated that for embodiments of the present invention in which each chip deflection surface **44** is at least partially located inside the first imaginary hexagon **H1**, the circumferential extent **E1** of each chip deflection surface **44** may advantageously exceed the hexagon side length **LH**, thus providing greater control of the flow of the chips.

As shown in Figs. 6 and 14, in the cross-section taken in the first vertical plane **PV1**, a fourth imaginary straight line **L4** perpendicular to the central axis **A1** may intersect the rake surface **42** and the chip deflection surface **44** at first and second intersections points **I1**, **I2**, respectively.

Also, as shown in Figs. 6 and 14, in the cross-section taken in the first vertical plane **PV1**, a fifth imaginary straight line **L5** tangential to the rake surface **42** at the first intersection point **I1** may form an acute rake surface angle **β1** with the fourth imaginary straight line **L4**, and a sixth imaginary straight line **L6** tangential to the chip deflection surface **44** at the second intersection point **I1** may form an acute deflection surface angle **β2** with the fourth imaginary straight line **L4**.

In some embodiments of the present invention, the deflection surface angle **β2** may be greater than the rake surface angle **β1**.

Also in some embodiments of the present invention, the deflection surface angle **β2** may be at least 5 degrees greater than the rake surface angle **β1**, i.e. $\beta 2 \geq \beta 1 + 5°$.

As shown in Figs. 1, 2, 9 and 10, each upper corner peripheral edge **38** may include a ramping cutting edge **48** and a curved corner cutting edge **50**, and the ramping cutting edge **48** may be spaced apart from its associated primary cutting edge **40** by the curved corner cutting edge **50**.

In some embodiments of the present invention, each curved corner cutting edge **50** may extend between the first end point **N1** of its associated primary cutting edge **40** and its associated ramping cutting edge **48**.

Also in some embodiments of the present invention, each primary cutting edge **40** may tangentially adjoin its associated curved corner cutting edge **50** at its first end point **N1**.

It should be appreciated that the rake surface **42** adjacent each primary cutting edge **40** may also be delimited by the ramping cutting edge **48** and the curved corner cutting edge **50** associated therewith.

As shown in Figs. 2 and 10, in the top view of the cutting insert **20**, **120**, a seventh imaginary straight line **L7** tangential to each ramping cutting edge **48** may form an acute ramp angle **ψ1** with its associated first imaginary straight line **L1**.

In some embodiments of the present invention, the acute ramp angle **ψ1** may be greater than 45 degrees, i.e. $45° < \psi 1 < 90°$.

As shown in Figs 9 to 11, each upper corner peripheral edge **38** of the second embodiment cutting insert **120** may include a straight wiper edge **52** extending between its associated curved corner cutting edge **50** and its associated ramping cutting edge **48**.

Each wiper edge **52** may tangentially adjoin its associated curved corner cutting edge **50**.

As shown in Figs. 7 and 15, in a partial cross-section taken along one of the ramping cutting edges **48**, each corner surface **34** may include a positively inclined ramping relief surface **54** adjacent its associated ramping cutting edge **48**.

It should be appreciated that the term "positively inclined" constitutes extension of the ramping relief surface **54** on the same side of a reference line **LV** parallel to the central axis **A1** and containing the associated ramping cutting edge **48**, as the adjacent rake surface **42**.

In some embodiments of the present invention, the lower surface **24** may have three lower abutment recesses **56** circumferentially spaced around the base surface **36**, and each lower abutment recess **56** may include a radially outward facing lower abutment surface **58**.

As shown in Figs. 8 and 16, in a cross-section taken in a fifth horizontal plane **PH5** perpendicular to the central axis **A1** and intersecting the three lower abutment surfaces **58**, the three lower abutment surfaces **58** may define three sides of a second imaginary triangle **T2**.

Also, as shown in Figs. 8 and 16, the second imaginary triangle **T2** has three imaginary second bisector lines **LB2**, each imaginary second bisector line **LB2** containing one of the second imaginary triangle's three corners and bisecting its non-adjacent side.

It should be appreciated that the second imaginary triangle **T2** is an equilateral triangle having its center contained in the central axis **A1**.

In some embodiments of the present invention, each lower abutment surface **58** may intersect one of the three side surfaces **32**.

Also in some embodiments of the present invention, each lower abutment surface **58** may be planar and non-parallel to the central axis **A1**.

As shown in Figs. 4 and 12, in a bottom view of the cutting insert **20**, **120**, each lower abutment surface **58** may not extend outside the first imaginary triangle **T1**, thus providing a compact means for mounting the cutting insert **20**, **120**.

As shown in Figs. 8 and 16, the first and second imaginary triangles **T1**, **T2** may both be centered about the central axis **A1**. Additionally, the second imaginary triangle **T2** may be rotationally offset from the first imaginary triangle **T1** by an offset angle **δ1**, thus providing a wider range of mounting options when utilizing at least one of the three side surfaces **32** and at least one of the three lower abutment surfaces **58**.

In some embodiments of the present invention, the offset angle **δ1** may be less than or equal to 30 degrees, i.e. $\delta 1 \leq 30°$.

Also in some embodiments of the present invention, the offset angle **δ1** may be equal to or greater than 15 degrees and less than or equal to 30 degrees, i.e. $15° \leq \delta 1 \leq 30°$.

As shown in Figs. 17 to 20, an additional aspect of the present invention relates to a rotary cutting tool **60** comprising a cutting body **62** and at least one of the aforementioned indexable cutting inserts **20**. Each cutting insert **20** is removably secured in an insert receiving pocket **64** of the cutting body **62**.

Although first embodiment cutting inserts **20** are retained in the rotary cutting tool **60** shown in Figs. 17 to 19, it should be appreciated that second embodiment cutting inserts **120** are interchangeable therewith, by virtue of the versatile mounting means provided.

As shown in Figs. 17 to 19, the cutting tool **60** may be rotatable about a tool axis **AT** defining a forward-rearward direction **DF**, **DR**, and each insert receiving pocket **64** may open out at a forward end surface **66** of the cutting body **62**.

In some embodiments of the present invention, as shown in Fig. 19, only one of the three upper corner peripheral edges **38** of each cutting insert **20** may serve as an operative upper corner peripheral edge **38'**, and the operative upper corner peripheral edge **38'** may contain an axially forwardmost point **NA** of its associated upper peripheral edge **30**.

Also in some embodiments of the present invention, the curved corner cutting edge **50** of the operative upper corner peripheral edge **38'** may contain the axially forwardmost point **NA**. In other words, in the assembled cutting tool **60**, the axially forwardmost point **NA** may be located on the curved corner cutting edge **50** associated with the operative upper corner peripheral edge **38'**.

Further in some embodiments of the present invention, the primary cutting edge **40** and the ramping cutting edge **48** of the operative upper corner peripheral edge **38'** may diverge in the rearward direction **DR**.

As shown in Fig. 19, the cutting tool **60** may be 'set-up' for cutting operations with a feed direction **FD** perpendicular to the tool axis **AT**, and the primary cutting edge **40** of the operative upper corner peripheral edge **38'** may be inclined at a lead angle **θ1** with respect to the feed

direction **FD**.

In some embodiments of the present invention, the lead angle **θ1** may be at least 10 degrees and at most 90 degrees, i.e. $10° \leq \theta 1 \leq 90°$, thus providing for a wide range of milling operations.

For embodiments in which first embodiment cutting inserts **20** are retained in the rotary cutting tool **60**, as shown in Fig. 19, the lead angle **θ1** may be 15 degrees, i.e. $\theta 1 = 15°$.

For embodiments in which second embodiment cutting inserts **120** are retained in the rotary cutting tool **60** (not shown), the lead angle **θ1** may be 90 degrees, i.e. $\theta 1 = 90°$.

It should be appreciated that for cutting operations in which the feed direction **FD** is perpendicular to the tool axis **AT**, the ramping cutting edge **48** of the operative upper corner peripheral edge **38'** is inoperative.

It should also be appreciated that the ramping cutting edge **48** of the operative upper corner peripheral edge **38'** becomes operative for cutting operations in which the feed direction **FD** is downwardly inclined from that shown in Fig. 18.

As shown in Fig. 18, the primary cutting edge **40** of the operative upper corner peripheral edge **38'** may be inclined at a positive axial rake angle **μ1** with respect to the tool axis **AT**.

As shown in Figs. 17 and 20, each insert receiving pocket **64** may have a seat surface **68** and spaced apart first and second pocket walls **70**, **72** transverse to the seat surface **68**.

In some embodiments of the present invention, the first pocket wall **70** may face radially outwardly and oppose radial cutting forces acting on the operative upper corner peripheral edge **38'**.

Also in some embodiments of the present invention, the second pocket wall **72** may face axially forwardly and oppose axial cutting forces acting on the operative upper corner peripheral edge **38'**.

As shown in Fig. 17, the first and second pocket walls **70**, **72** of each insert receiving pocket **64** may diverge in the forward direction **DF**.

Also, as shown in Fig. 17, the tool axis **AT** may define a direction of rotation **R**, and the seat surface **68** of each insert receiving pocket **64** may face the direction of rotation **R**.

In some embodiments of the present invention, the seat surface **68** may be planar.

In other embodiments of the present invention (not shown), the seat surface **68** may include a plurality of coplanar seat sub-surfaces.

Also in some embodiments of the present invention, each cutting insert **20** may be removably secured in its respective insert receiving pocket **64** by means of a clamping screw **74** extending through the central bore **28** and engaging a threaded bore **76** in the seat surface **68**.

In a front view of the insert receiving pocket **64**, as shown in Fig. 20, the first and second pocket walls **70**, **72** may form an external pocket angle **σ1**.

It should be appreciated that use of the term "external angle" throughout the description and claims refers to an angle between two planar surface components as measured external to the member on which these surface components are formed.

In some embodiments of the present invention, the pocket angle **σ1** may be greater than 60 degrees and less than or equal to 90 degrees, i.e. $60° < \sigma1 \leq 90°$, thus enabling the cutting insert **20,** to be mounted in the insert receiving pocket **64** with a high level of stability.

Also in some embodiments of the present invention, the pocket angle **σ1** may be equal to or greater than 75 degrees and less than or equal to 90 degrees, i.e. $75° < \sigma1 \leq 90°$

For each index position of each cutting insert **20** in its respective insert receiving pocket **64**:

the insert's base surface **36** may make contact with the seat surface **68**,

only one of the insert's three side surfaces **32** may be an operative side surface **32'**, and make contact with the first pocket wall **70**, and

only one of the insert's three lower abutment surfaces **58** may be an operative lower abutment surface **58'**, and make contact with the second pocket wall **72**.

Apart from these said instances of contact, each cutting insert **20** may make no additional contact with its respective insert receiving pocket **64**.

In some embodiments of the present invention, the operative side surface **32'** may not be circumferentially adjacent the corner surface **34** which intersects the upper surface **22** to form the operative upper corner peripheral edge **38'**.

Also in some embodiments of the present invention, as shown in Fig. 21, the first vertical plane **PV1** associated with the operative upper corner peripheral edge **38'** may intersect the first pocket wall **70**, such that a first pocket wall reaction force opposing the radial cutting forces is

advantageously directed through the central axis **A1** and the clamping screw **74**.

Although the present invention has been described to a certain degree of particularity, it should be understood that various alterations and modifications could be made without departing from the spirit or scope of the invention as hereinafter claimed.

CLAIMS

What is claimed is:

1. An indexable triangular-shaped cutting insert (20, 120) comprising:

opposing upper and lower surfaces (22, 24) with a peripheral surface (26) extending therebetween and a central axis (A1) extending therethrough,

the lower surface (24) having a downward facing planar base surface (36) defined by a first horizontal plane (PH1) perpendicular to the central axis (A1),

the peripheral surface (26) intersecting the upper surface (22) to form a continuous upper peripheral edge (30), and having three side surfaces (32) circumferentially alternating with three corner surfaces (34),

each corner surface (34) intersecting the upper surface (22) to form an upper corner peripheral edge (38), and each upper corner peripheral edge (38) having a primary cutting edge (40) extending from a first end point (N1) to a second end point (N2),

wherein in a cross-section taken in a second horizontal plane (PH2) perpendicular to the central axis (A1) and intersecting the three side surfaces (32), the three side surfaces (32) define three sides of a first imaginary triangle (T1) and three non-adjacent sides of a first imaginary hexagon (H1), and

wherein in a top view of the cutting insert (20, 120):

each side of the first imaginary triangle (T1) traverses two upper corner peripheral edges (38),

first and second imaginary straight lines (L1, L2) tangential to each primary cutting edge (40) at its first and second end points (N1, N2), respectively, are either collinear or form an obtuse primary bend angle ($\alpha 1$) of greater than 175 degrees,

each primary cutting edge (40) has a primary length (LP) between its first and second end points (N1, N2) greater than half the hexagon side length (LH) of the first imaginary hexagon (H1), and

at least one side of the first imaginary triangle (T1) traverses each primary cutting edge (40).

2. The cutting insert (20, 120) according to claim 1, wherein in the top view of the cutting insert (20, 120):

the first imaginary triangle's three corners are located outside the upper peripheral edge (30).

3. The cutting insert (20, 120) according to claim 1 or 2, wherein in the top view of the cutting insert (20):

the first imaginary hexagon's six corners are located inside the upper peripheral edge (30).

4. The cutting insert (20, 120) according to any one of the preceding claims, wherein:

the first imaginary triangle (T1) has three imaginary first bisector lines (LB1), each imaginary first bisector line (LB1) containing one of the first imaginary triangle's three corners and bisecting its non-adjacent side, and

wherein in the top view of the cutting insert (20, 120):

each imaginary first bisector line (LB1) intersects one of the upper corner peripheral edges (38), and

each upper corner peripheral edge (38) does not exhibit mirror symmetry about its associated imaginary first bisector line (LB1).

5. The cutting insert (20, 120) according to any one of the preceding claims, wherein:

each primary cutting edge (40) slopes downwardly from its first end point (N1) to its second end point (N2).

6. The cutting insert (20, 120) according to any one of the preceding claims, wherein:

the primary length (LP) is greater than two-thirds of the hexagon side length (LH).

7. The cutting insert (20, 120) according to any one of the preceding claims, wherein in the top view of the cutting insert (20, 120):

each upper corner peripheral edge (38) is traversed only once by the same side of the first imaginary triangle (T1).

8. The cutting insert (20, 120) according to any one of the preceding claims, wherein:

the upper surface (22) includes a rake surface (42) adjacent each primary cutting edge (40) and a chip deflection surface (44) between each rake surface (42) and a central top surface (46).

9. The cutting insert (20, 120) according to claim 8, wherein:

a central bore (28) coaxial with the central axis (A1) intersects the upper and lower surfaces (22, 24), and

the top surface (46) entirely surrounds the central bore (28).

10. The cutting insert (20, 120) according to claim 8 or 9, wherein in the top view of the cutting insert (20, 120):

each chip deflection surface (44) is at least partially located inside the first imaginary hexagon (H1).

11. The cutting insert (20, 120) according to any one of claims 8 to 10, wherein:

the top surface (46) is planar and defined by a third horizontal plane (PH3) perpendicular to the central axis (A1).

12. The cutting insert (20, 120) according to claim 11, wherein:

no portion of the cutting insert (20, 120) is located upward of the third horizontal plane (PH3).

13. The cutting insert (20, 120) according to any one of claims 8 to 12, wherein in a cross-section taken in a first vertical plane (PV1) containing the central axis (A1) and a mid-point (N3) of one of the primary cutting edges (40):

the rake surface (42) slopes downwardly away from the primary cutting edge (40), and

the chip deflection surface (44) slopes upwardly towards the top surface (46).

14. The cutting insert (20, 120) according to claim 13, wherein in the cross-section taken in the first vertical plane (PV1):

a fourth imaginary straight line (L4) perpendicular to the central axis (A1) intersects the rake surface (42) and the chip deflection surface (44) at first and second intersections points (I1, I2), respectively,

a fifth imaginary straight line (L5) tangential to the rake surface (42) at the first intersection point (I1) forms an acute rake surface angle ($\beta 1$) with the fourth imaginary straight line (L4),

a sixth imaginary straight line (L6) tangential to the chip deflection surface (44) at the second intersection point (I1) forms an acute deflection surface angle ($\beta 2$) with the fourth imaginary straight line (L4), and

the deflection surface angle ($\beta 2$) is greater than the rake surface angle ($\beta 1$).

15. The cutting insert (20, 120) according to claim 14, wherein:

the deflection surface angle ($\beta 2$) is at least 5 degrees greater than the rake surface angle ($\beta 1$).

16. The cutting insert (20, 120) according to any one of the preceding claims, wherein:

each upper corner peripheral edge (38) includes a ramping cutting edge (48) and a curved corner cutting edge (50), and

each curved corner cutting edge (50) extends between the first end point (N1) of its associated primary cutting edge (40) and its associated ramping cutting edge (48).

17. The cutting insert (20, 120) according to claim 16, wherein in the top view of the cutting insert (20, 120):

a seventh imaginary straight line (L7) tangential to each ramping cutting edge (48) forms an acute ramp angle (ψ1) with its associated first imaginary straight line (L1), and

the acute ramp angle (ψ1) is greater than 45 degrees.

18. A rotary cutting tool (60) rotatable about a tool axis (AT) defining a forward-rearward direction (DF, DR), and comprising:

a cutting body (62) having at least one insert receiving pocket (64); and

at least one cutting insert (20, 120) in accordance with any one of the preceding claims removably secured in the insert receiving pocket (64).

19. The rotary cutting tool (60) according to claim 18, wherein:

each insert receiving pocket (64) opens out at a forward end surface (66) of the cutting body (62), and

only one of the three upper corner peripheral edges (38) of the at least one cutting insert (20, 120) serves as an operative upper corner peripheral edge (38'), containing an axially forwardmost point (NA) of its associated upper peripheral edge (30).

20. The rotary cutting tool (60) according to claim 19, wherein:

each upper corner peripheral edge (38) includes a ramping cutting edge (48) and a curved corner cutting edge (50),

the ramping cutting edge (48) is spaced apart from its associated primary cutting edge (40) by the curved corner cutting edge (50), and

the axially forwardmost point (NA) is located on the curved corner cutting edge (50) of the operative upper corner peripheral edge (38').

21. The rotary cutting tool (60) according to claim 20, wherein:

the primary cutting edge (40) and the ramping cutting edge (48) of the operative upper corner peripheral edge (38') diverge in the rearward direction (DR).

22. The rotary cutting tool (60) according to any one of claims 19 to 21, wherein:

each insert receiving pocket (64) has a seat surface (68) and first and second pocket walls (70, 72) transverse to the seat surface (68), the first and second pocket walls (70, 72) forming an external pocket angle ($\sigma 1$) in a front view of the insert receiving pocket (64), and

the insert's lower surface (24) has three lower abutment recesses (56) circumferentially spaced around the base surface (36), each lower abutment recess (56) including a radially outward facing lower abutment surface (58),

and wherein:

the insert's base surface (36) makes contact with the seat surface (68),

only one of the insert's three side surfaces (32) is an operative side surface (32'), making contact with the first pocket wall (70), and

only one of the insert's three lower abutment surfaces (58) is an operative lower abutment surface (58'), making contact with the second pocket wall (72).

23. The rotary cutting tool (60) according to any one of claims 19 to 22, wherein:

the pocket angle ($\sigma 1$) is greater than 60 degrees and less than or equal to 90 degrees.

24. The rotary cutting tool (60) according to any one of claims 19 to 23, wherein:

a first vertical plane (PV1) containing the central axis (A1) and a mid-point (N3) of the primary cutting edge (40) of the operative upper corner peripheral edge (38') intersects the first pocket wall (70).

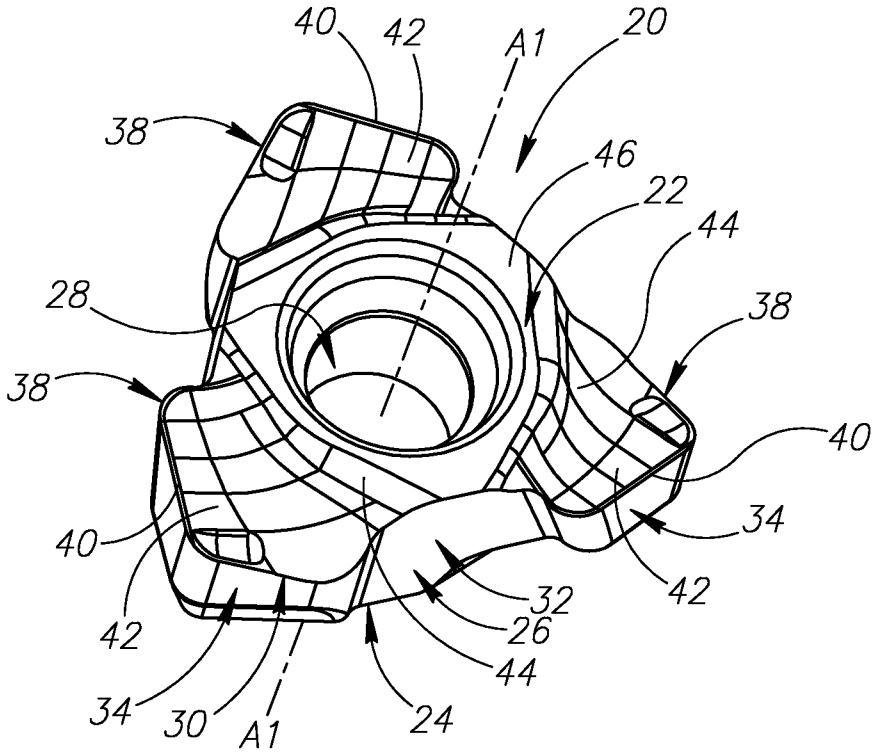
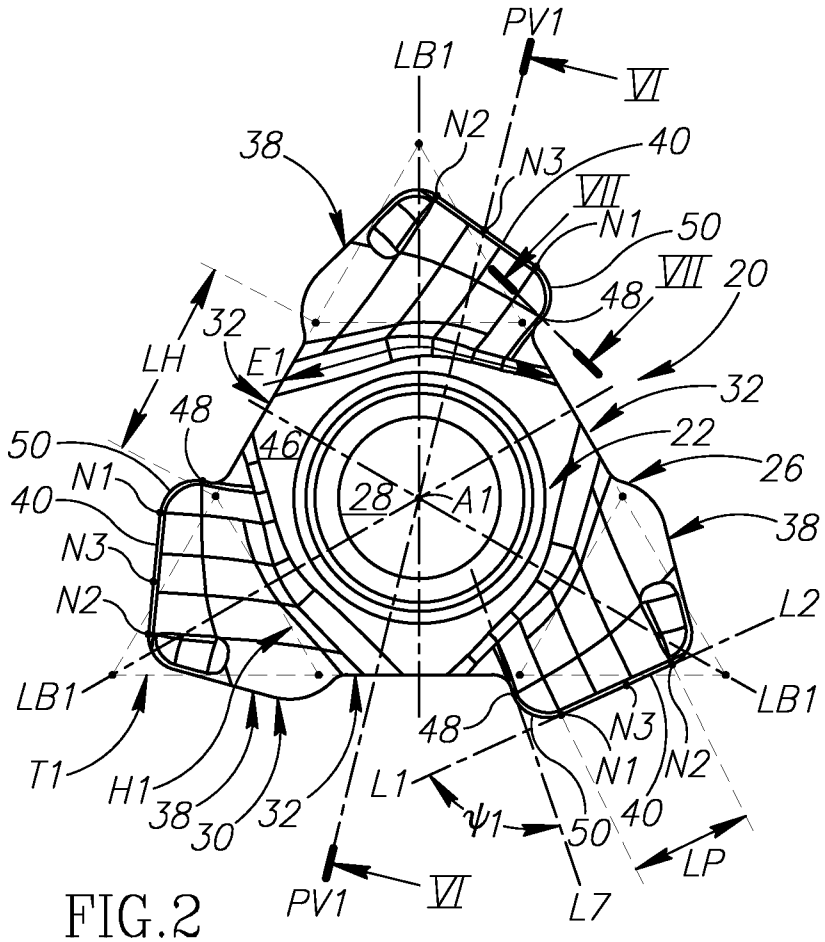

40
42
A1
20
38
46
22
44
28
38
38
40
40
34
42
32
26
42
44
34
30
A1
24

FIG.1


PV1
LB1
VI
N2
38
N3
40
VII
N1
50
VII
20
48
32
LH
E1
32
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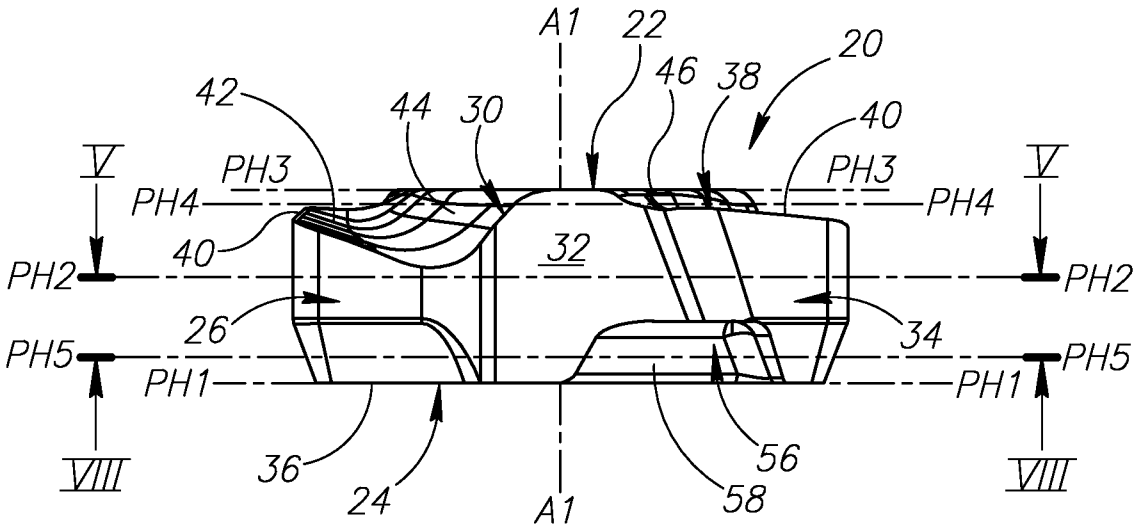
22
50
46
26
N1
28
A1
40
38
N3
N2
L2
LB1
LB1
48
T1
H1
38
30
32
N3
N1
N2
L1
ψ1
50
40
LP
PV1
VI
L7

FIG.2


A1
22
20
46
38
42
44
30
40
V
PH3
PH4
PH3
PH4
V
40
32
PH2
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26
34
PH5
PH5
PH1
PH1
VIII
VIII
36
24
A1
58
56

FIG.3

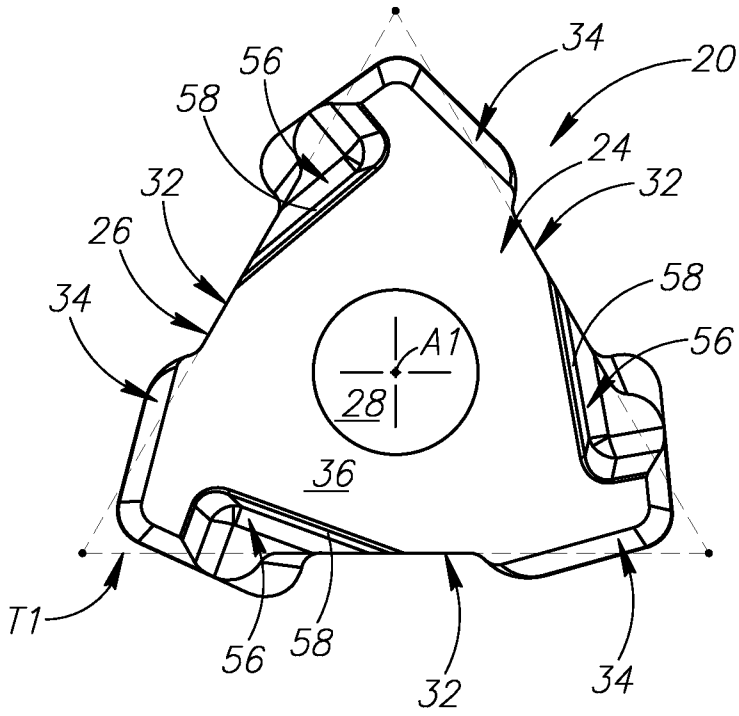

56
34
20
58
24
32
32
26
58
34
56
A1
28
36
T1
56
58
32
34

FIG.4

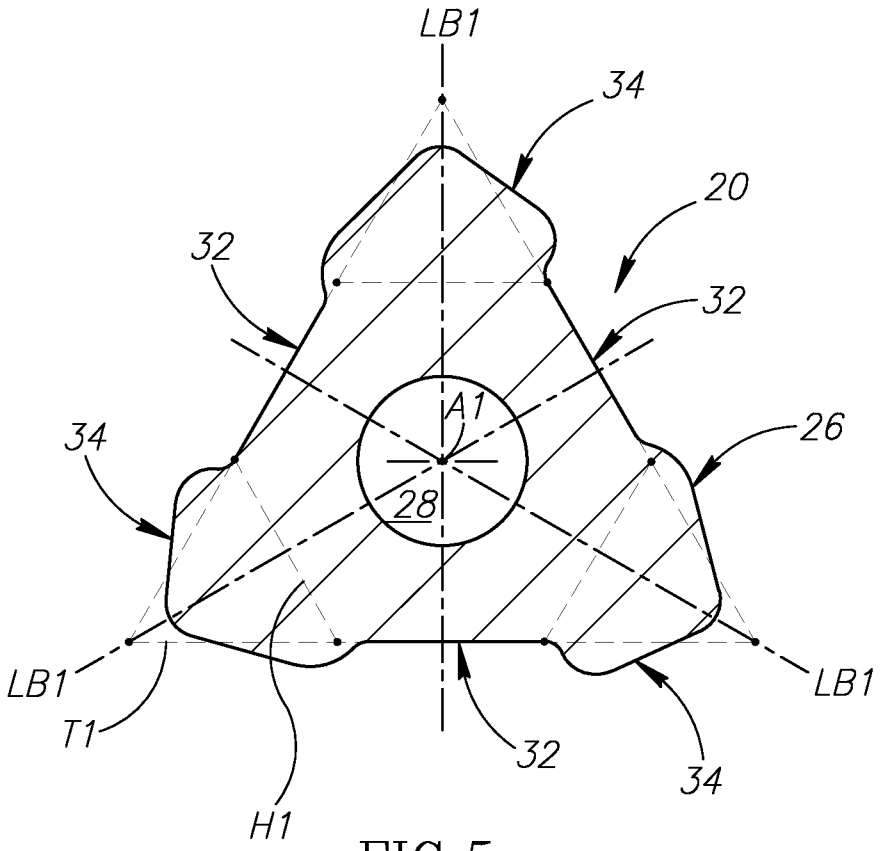

LB1
34
20
32
32
A1
34
26
28
LB1
LB1
T1
32
34
H1

FIG.5

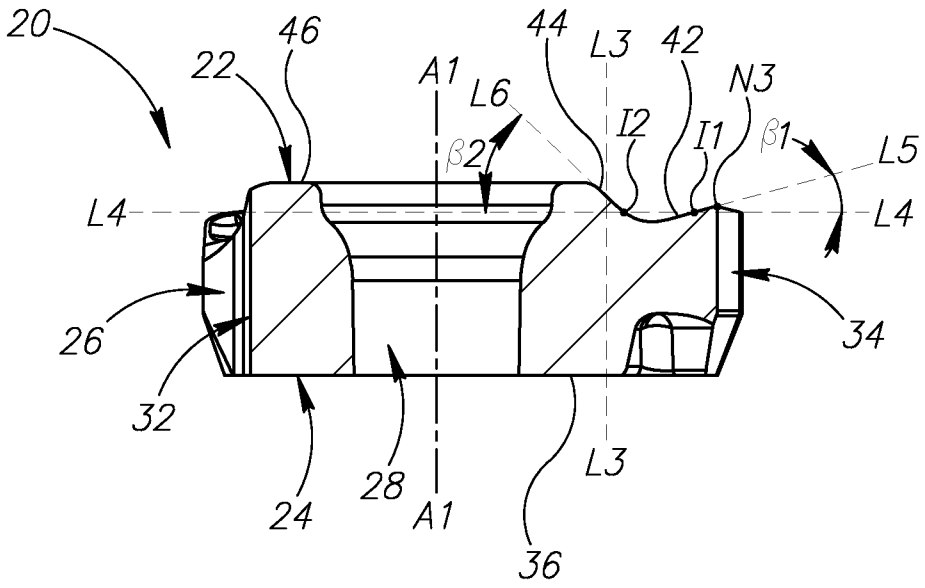

20
46
22
A1
44
L3
42
N3
L6
I2
I1
β1
L5
β2
L4
L4
26
34
32
24
28
A1
L3
36

FIG.6

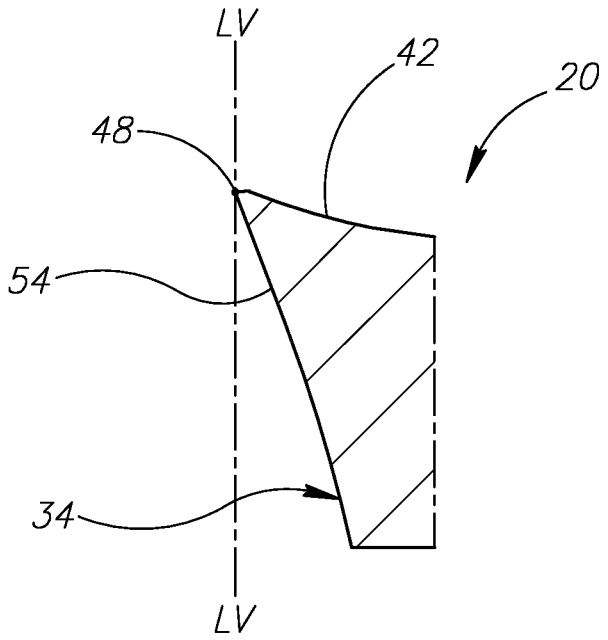

LV
42
20
48
54
34
LV

FIG.7

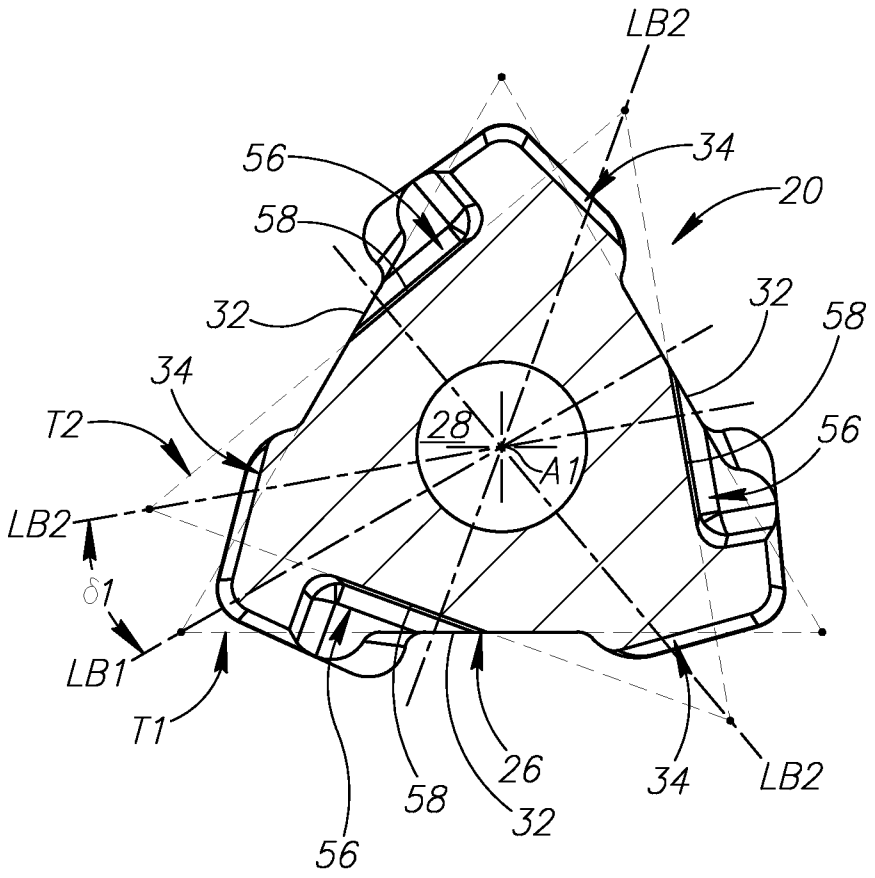

LB2
34
20
56
58
32
32
58
34
T2
28
56
A1
LB2
δ1
LB1
T1
56
58
26
32
34
LB2

FIG.8

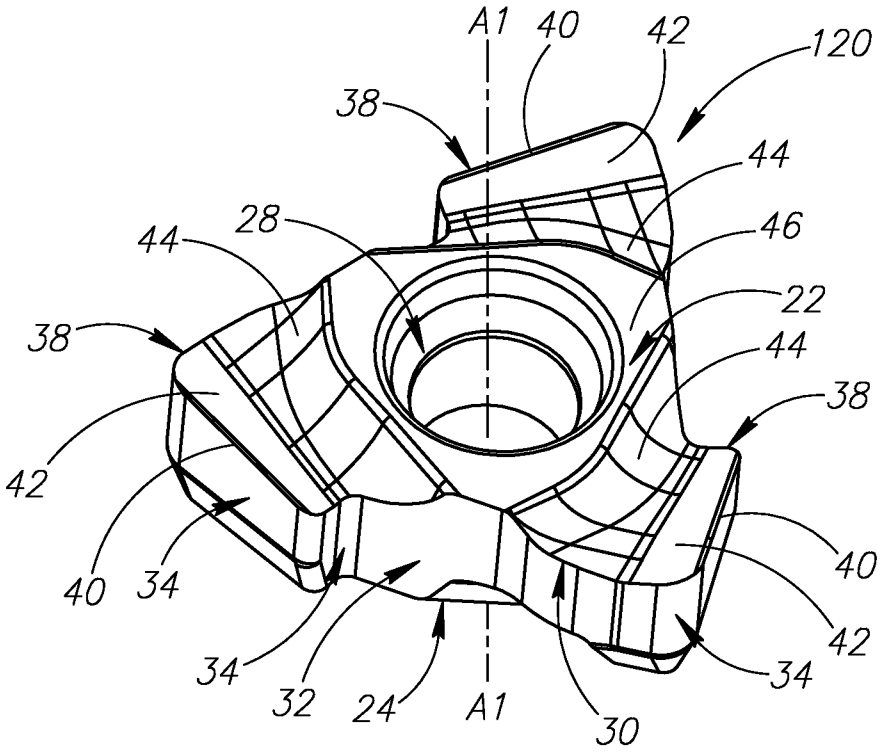
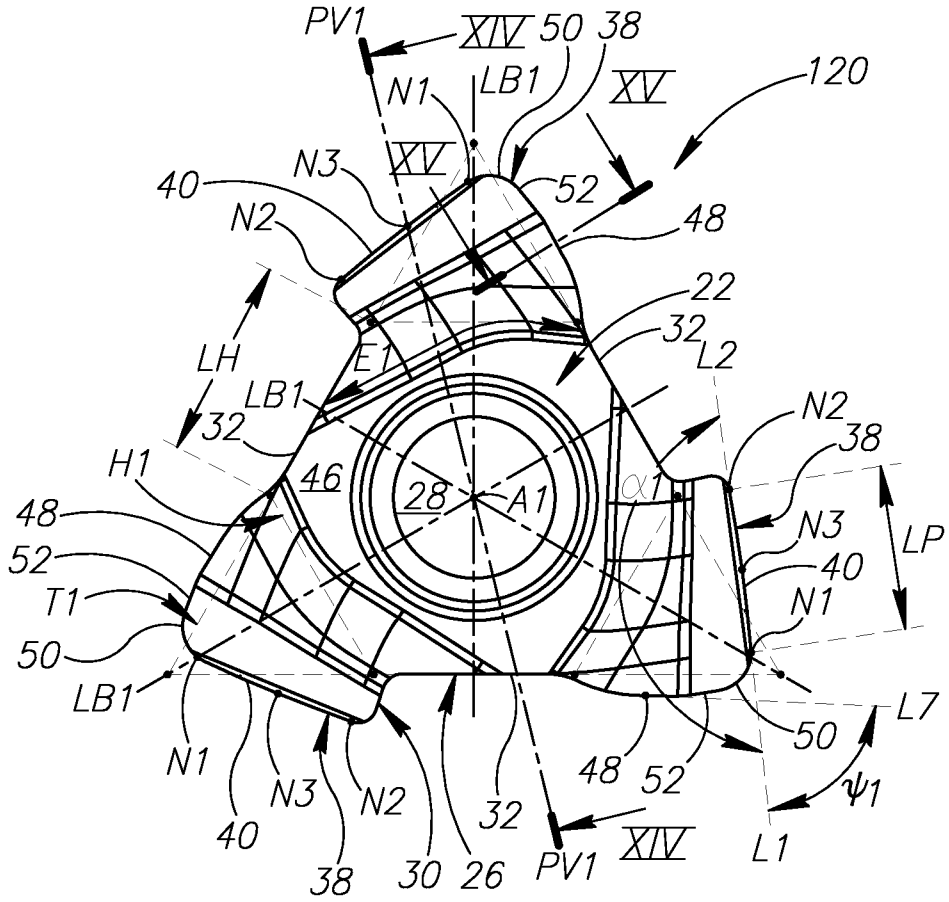

A1
40
42
120
38
44
28
46
22
34
32
24
30

FIG.9


PV1
XIV
50
38
LB1
XV
120
N1
N3
52
48
40
N2
22
32
LH
E1
L2
H1
46
28
A1
α1
N2
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N3
LP
40
N1
T1
L7
50
48
52
ψ1
L1
26
30

FIG.10

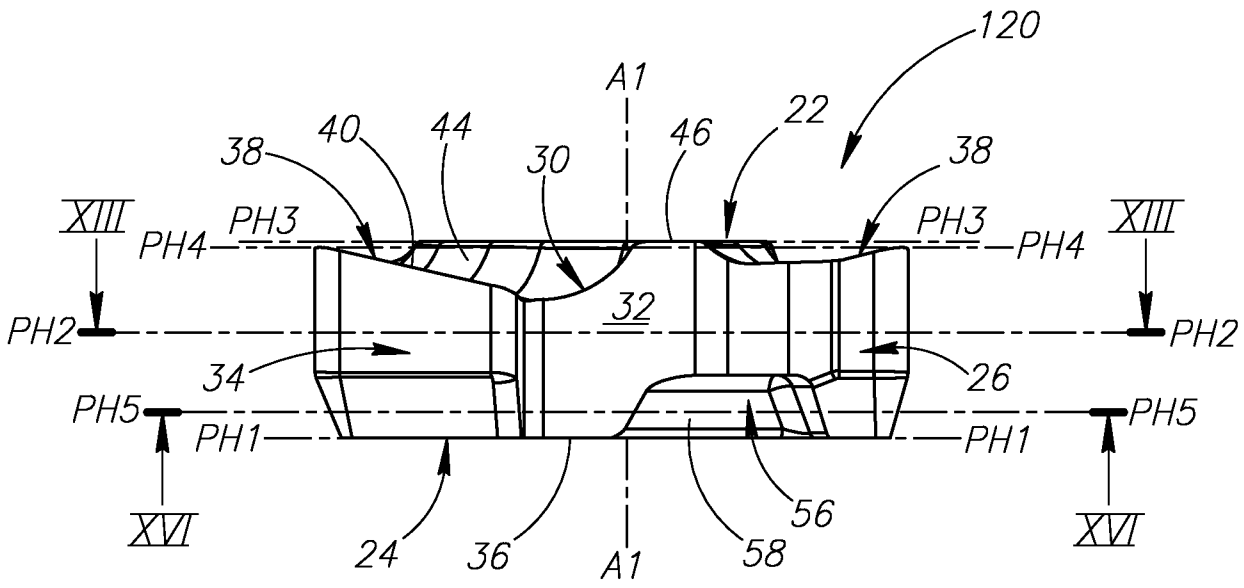
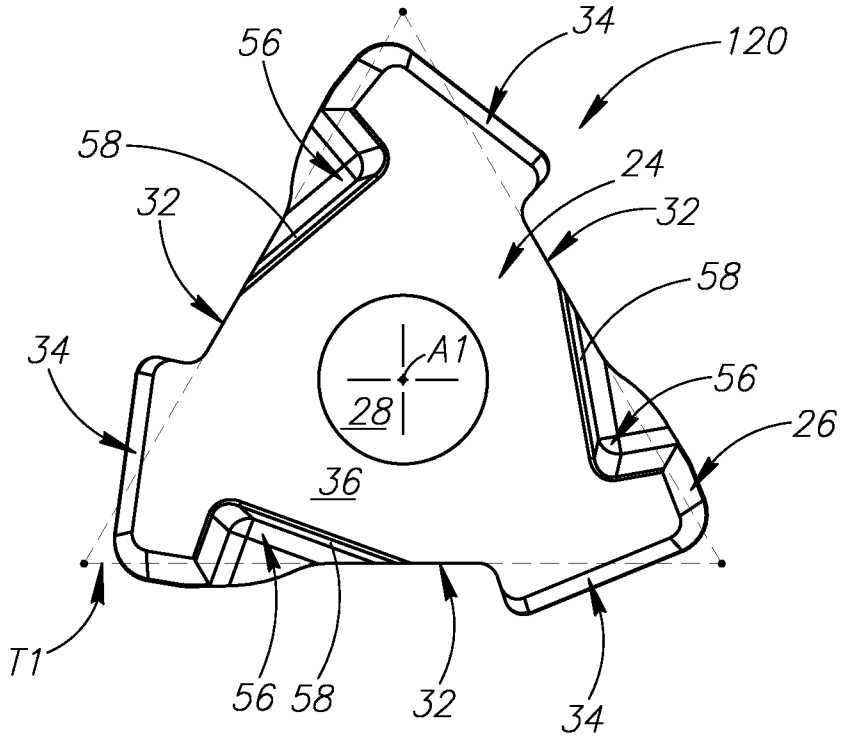

120
A1
22
38
40
44
30
46
38
XIII
PH4
PH3
PH3
PH4
XIII
PH2
32
PH2
34
26
PH5
PH1
PH1
PH5
XVI
24
36
A1
58
56
XVI

FIG.11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34
A1
28
56
26
36
T1
56
58
32
34

FIG.12

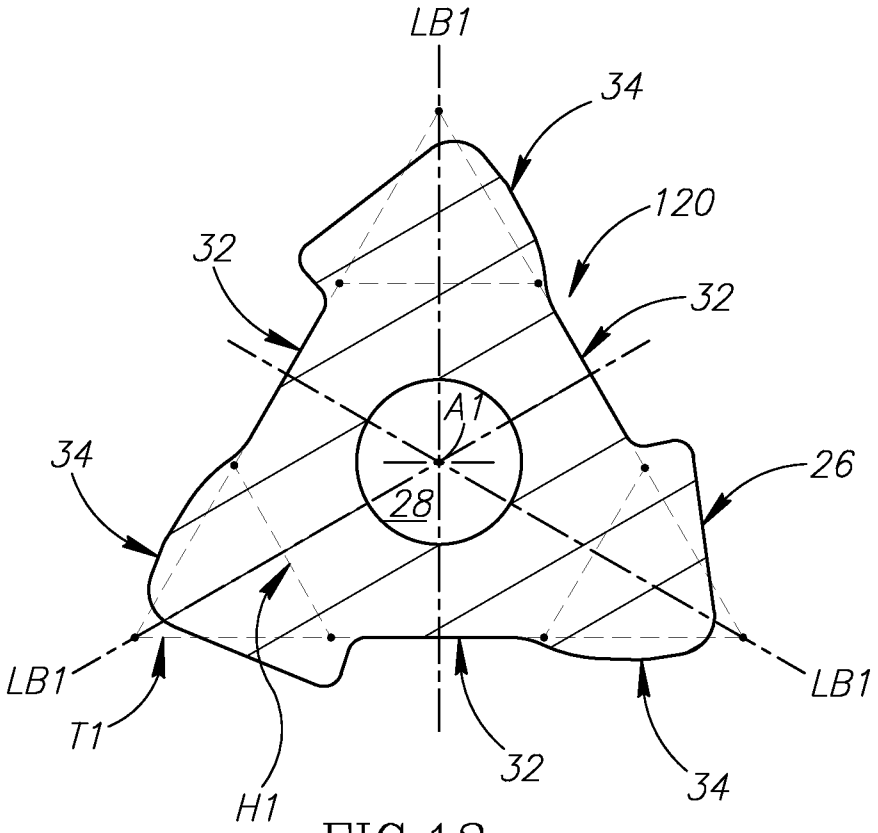
LB1
34
120
32
32
A1
34
26
28
LB1
LB1
T1
H1
32
34

FIG.13

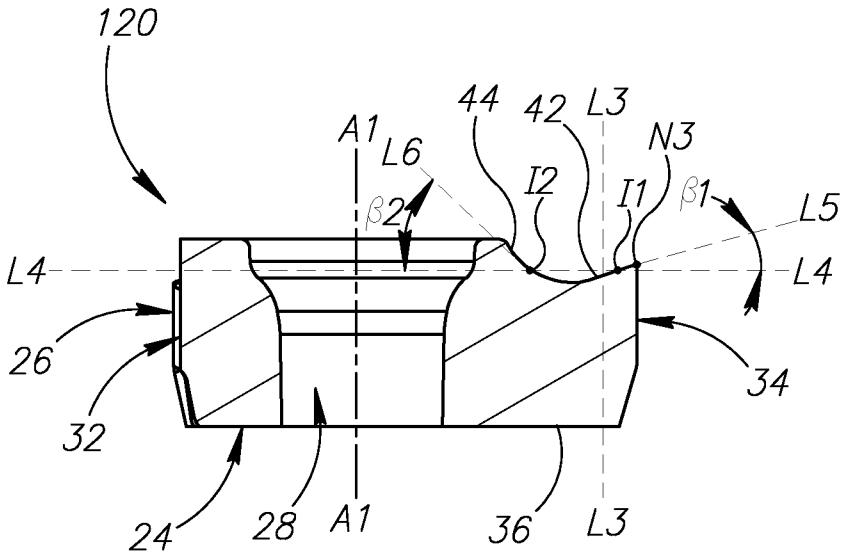
120
A1
L6
44
42
L3
N3
I2
I1
β1
L5
β2
L4
L4
26
34
32
24
28
A1
36
L3

FIG.14

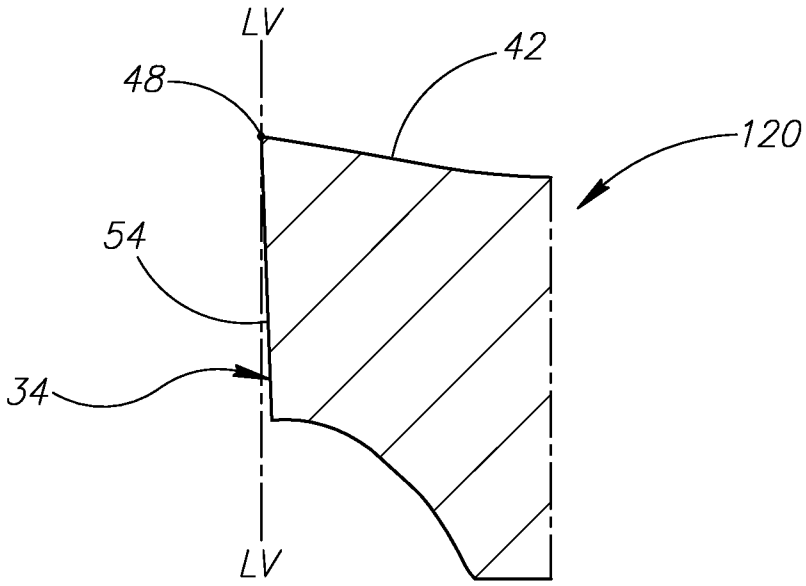
LV
42
48
120
54
34
LV

FIG.15

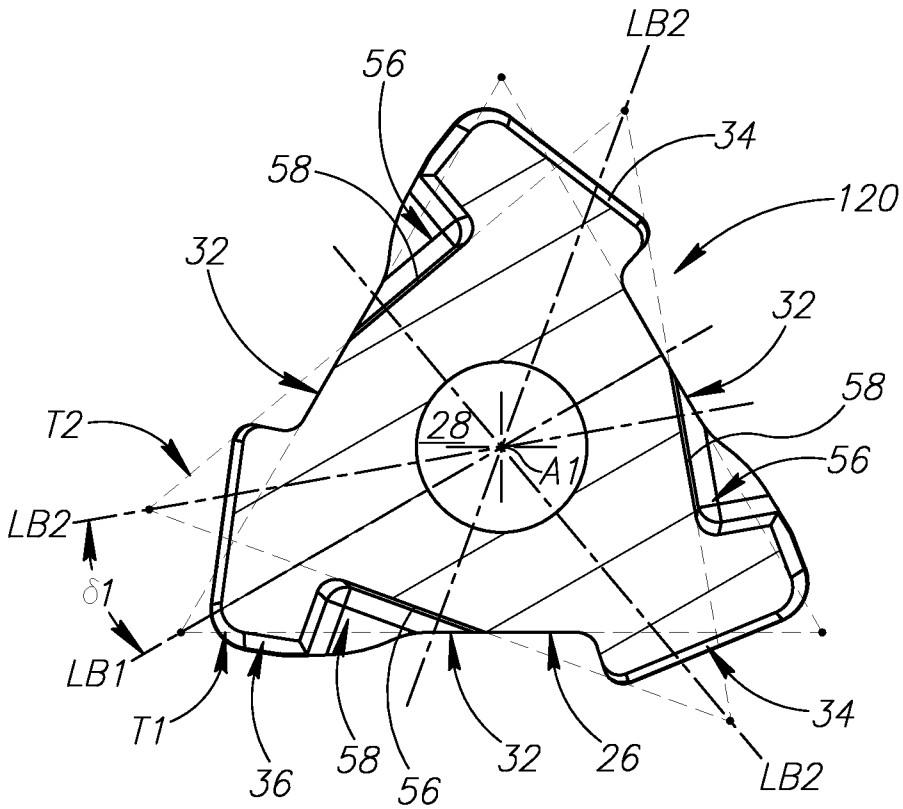
LB2
56
34
58
120
32
32
58
T2
28
A1
56
LB2
δ1
LB1
T1
36
58
56
32
26
34
LB2

FIG.16

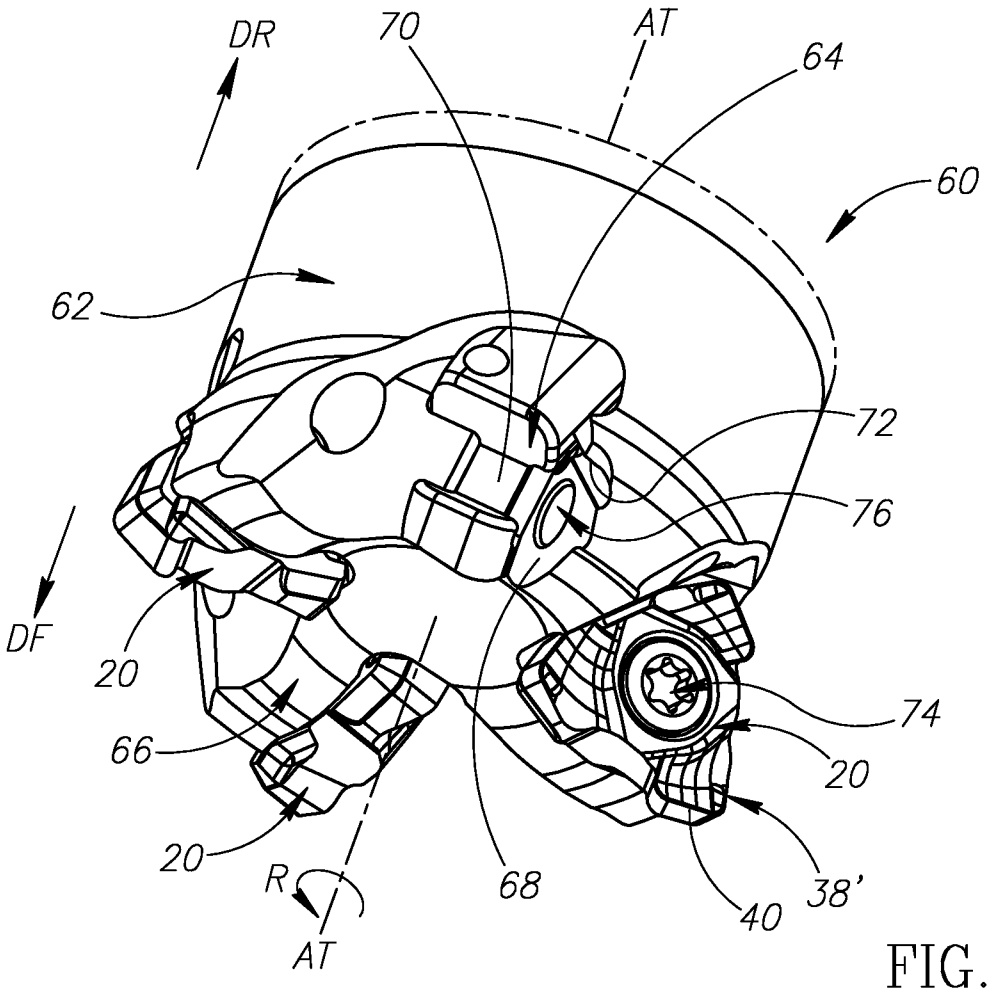
DR
70
AT
64
60
62
72
76
DF
20
74
66
20
20
R
68
40
38'
AT

FIG.17

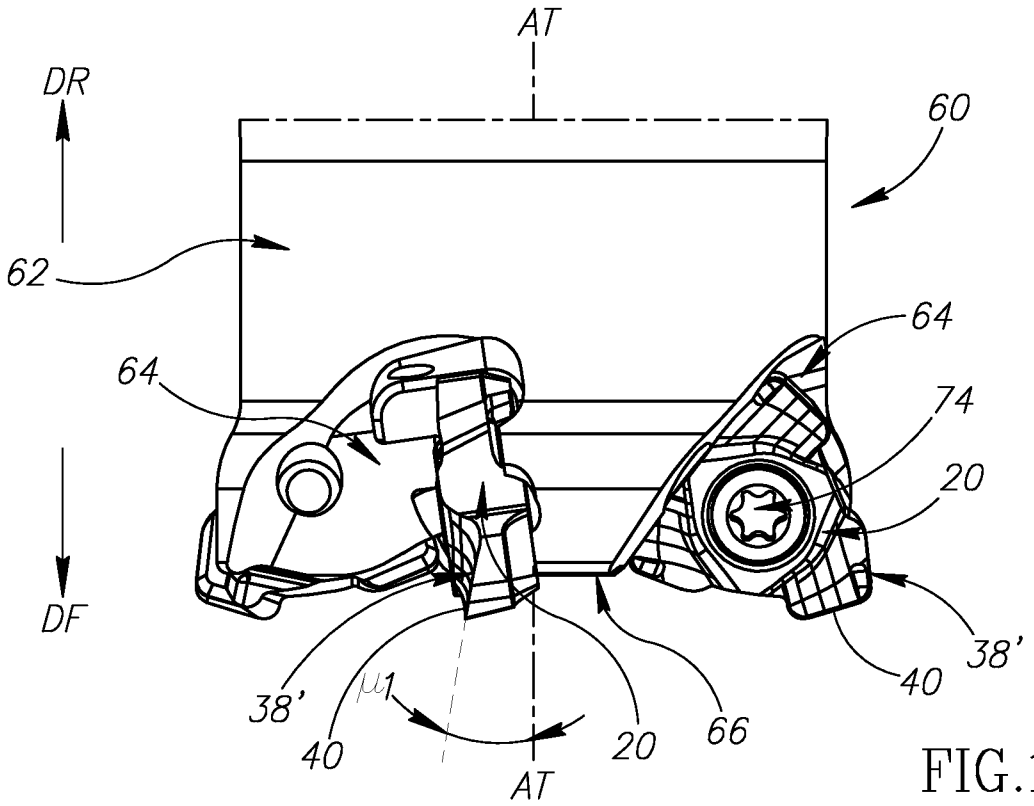
AT
DR
60
62
64
64
74
20
DF
38'
40
38'
μ1
20
66
40
AT

FIG.18

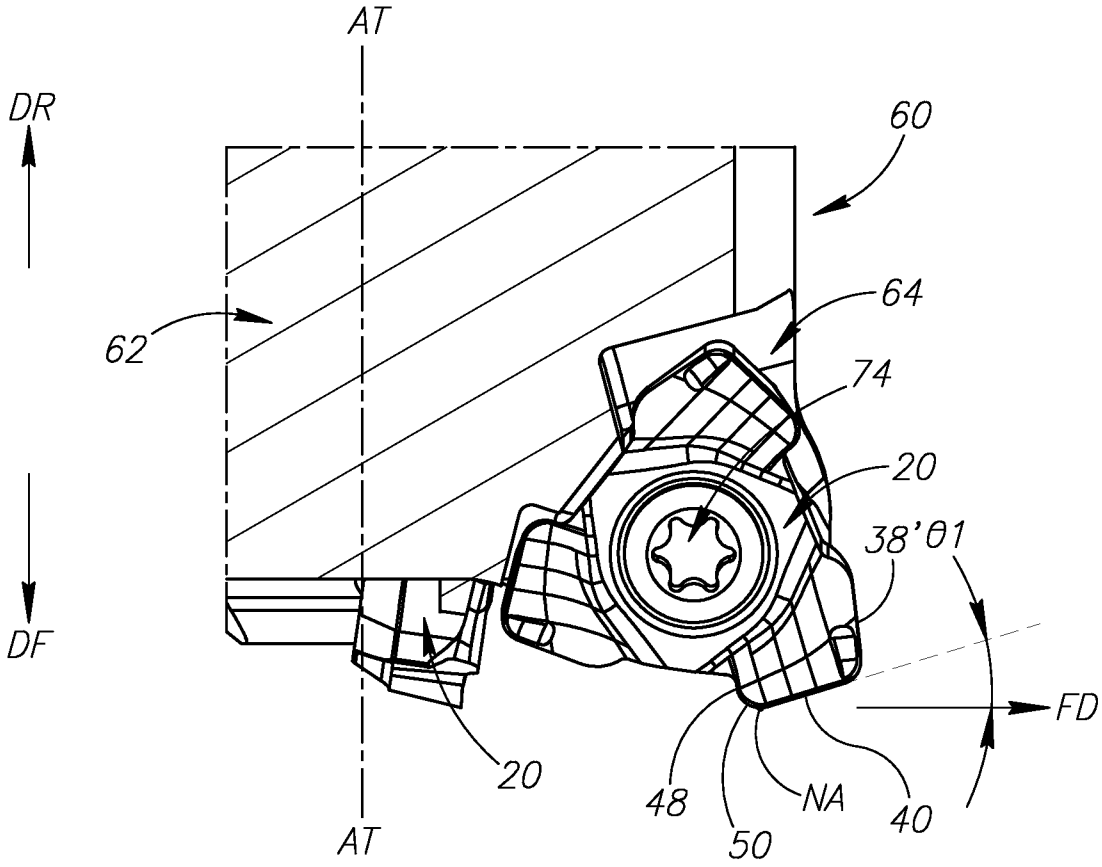

FIG.19

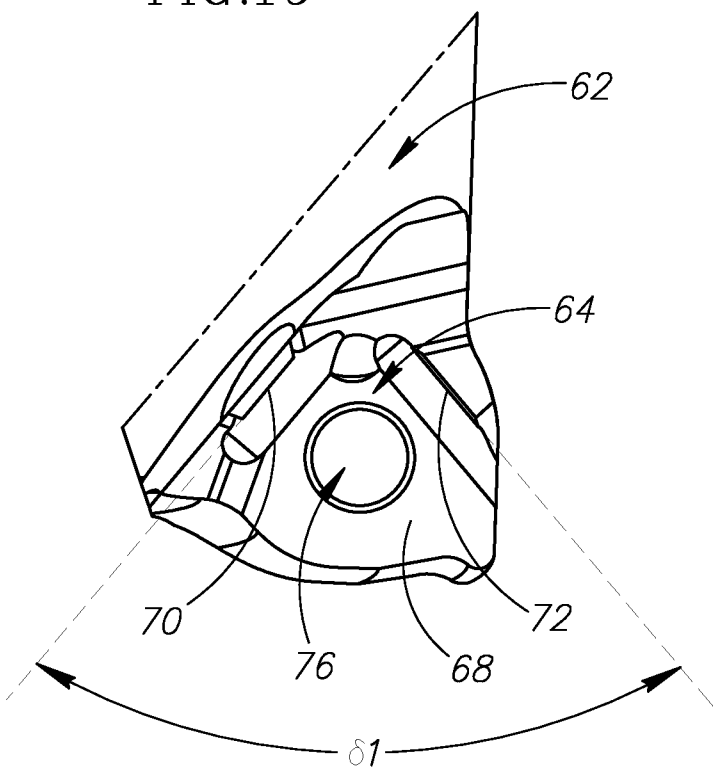

FIG.20

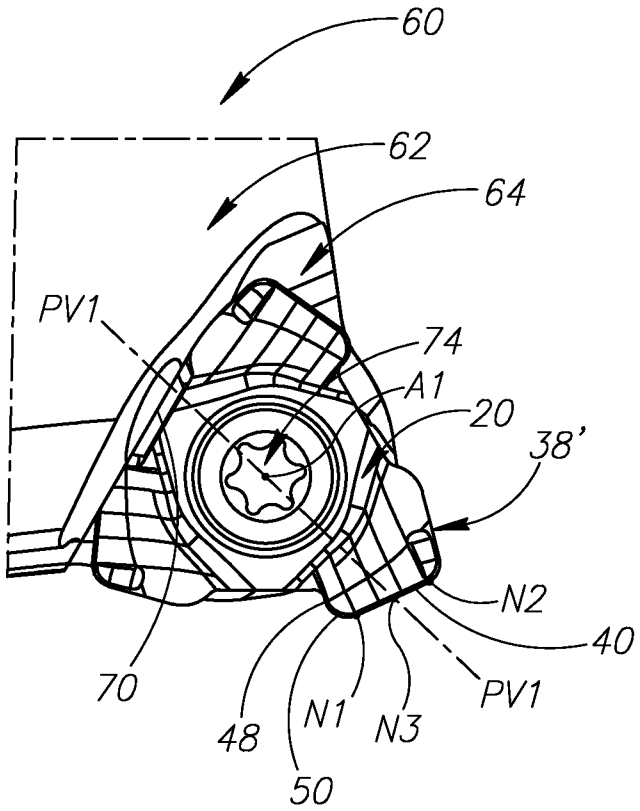

FIG.21

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2018/051126

A. CLASSIFICATION OF SUBJECT MATTER
INV. B23C5/10 B23C5/22
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B23B B23C

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2006 075913 A (MITSUBISHI MATERIALS CORP) 23 March 2006 (2006-03-23) paragraphs [0018], [0038] figures 1-4, 16, 17, 21-23	1-16, 18-24 17
X	US 6 527 485 B1 (LITTLE ROGER WARREN [US]) 4 March 2003 (2003-03-04) figures 1-4	1-3,5,6, 8-15,18
X	EP 2 213 399 A1 (VARGUS LTD [IL]) 4 August 2010 (2010-08-04) figures 1-5	1-6, 8-15,18
X	EP 1 346 789 A1 (MITSUBISHI MATERIALS CORP [JP]) 24 September 2003 (2003-09-24) paragraphs [0024], [0036] figures 1, 2, 5, 8, 13	1,16, 18-21

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 February 2019	19/02/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Schäfer, Lisa

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IL2018/051126

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		DE 60309948 T2	20-09-2007
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