



(51) International Patent Classification:

B23B 51/00 (2006.01) *B23D 1/02* (2006.01)

(21) International Application Number:

PCT/IL2022/051097

(22) International Filing Date:

18 October 2022 (18.10.2022)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

17/527,638 16 November 2021 (16.11.2021) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH,

(54) Title: CUTTING HEAD HAVING FOUR CUTTING PORTIONS AND TWO CONVEX CLAMPING SURFACES, AND ROTARY CUTTING TOOL

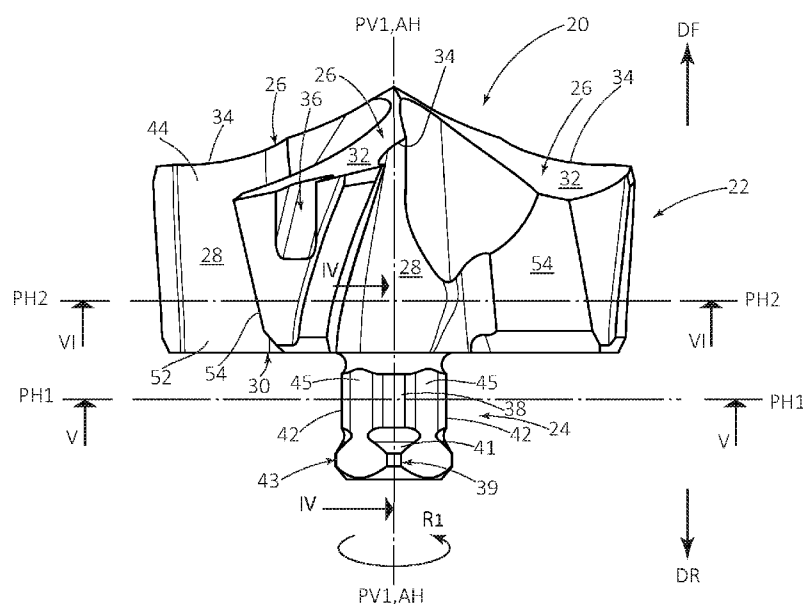


Fig. 2

(57) Abstract: A cutting head (20) rotatable about a head axis AH has a cap portion (22) and a rigid mounting protuberance (24) joined to the cap portion. The cap portion has exactly four cutting portions (26) circumferentially alternating with four head flutes (28), and a head base surface (30) facing in an axially rearward direction DR. The mounting protuberance extends axially rearwardly from the head base surface, and has exactly two circumferentially spaced apart convex clamping surfaces (38). In a cross-section taken in a first horizontal plane PHI perpendicular to the head axis and intersecting the mounting protuberance, only the two clamping surfaces are circumscribed by an imaginary first circle C1 having a first diameter D1 and a center coincident with the head axis. A rotary cutting tool (56) has an elongated tool shank (58) with a head receiving pocket (60) at a forward end thereof, and the cutting head of the type described above releasably secured to the head receiving pocket.

TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS,
ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

CUTTING HEAD HAVING FOUR CUTTING PORTIONS AND TWO CONVEX CLAMPING SURFACES, AND ROTARY CUTTING TOOL

FIELD OF THE INVENTION

The present invention relates to a rotary cutting tool and a cutting head having four cutting portions releasably secured to a tool shank associated therewith, for use in metal cutting processes in general, and for drilling operations in particular.

5

BACKGROUND OF THE INVENTION

Within the field of cutting tools used in drilling operations, there are some examples of cutting heads having more than two cutting portions releasably secured to a tool shank associated therewith.

10 US 10,173,271 discloses a tool shank having a head receiving pocket at a forward end, and a plurality of chip flutes extending rearwardly therefrom along a longitudinal axis. The head receiving pocket has a support surface transverse to the longitudinal axis. A central recess is formed in the support surface and extends rearwardly therefrom. The central recess has a plurality of resiliently displaceable abutment portions circumferentially alternating with and spaced apart
15 by a plurality of intermediate portions. Each abutment portion has a radially inward facing abutment surface, and each intermediate portion has an intermediate surface intersecting two circumferentially adjacent abutment surfaces. A rotary cutting tool includes the shank and a cutting head releasably mounted thereto. The cutting head has a mounting portion provided with a base surface and an engagement member protruding therefrom. In an assembled position, the
20 engagement member is resiliently retained in the central recess against the plurality of abutment surfaces.

US 11,110,521 discloses a cutting head rotatable about a first axis, having a cap portion and a rigid mounting protuberance joined thereto. The cap portion has a plurality of cutting portions circumferentially alternating with a plurality of head chip flutes, and a head base surface
25 facing in an axial rearward direction. The mounting protuberance exhibits rotational symmetry

about the first axis, extends axially rearwardly from the head base surface, and has a plurality of circumferentially spaced apart convex clamping surfaces. The plurality of cutting portions define a cutting diameter, the plurality of head chip flutes are inscribed by an imaginary first circle having a first diameter, and the plurality of clamping surfaces are circumscribed by an imaginary second circle having a second diameter. The first diameter is greater than the second diameter, and the second diameter is less than forty percent of the cutting diameter.

It is an object of the present invention to provide an improved cutting head having four cutting portions.

It is also an object of the present invention to provide an improved cutting head having good stability when releasably secured to a tool shank.

It is a further object of the present invention to provide an improved tool shank having an extended useful life.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a cutting head rotatable about a head axis in a first direction of rotation, the head axis establishing an axial forward direction and an axial rearward direction opposite the axial forward direction, the cutting head comprising:

a cap portion having exactly four cutting portions circumferentially alternating with four head flutes, and a head base surface facing in the axial rearward direction,

each cutting portion having a front surface facing in the axial forward direction and intersecting a circumferentially adjacent and rotationally forward head flute with respect to the first direction of rotation to form a radially extending cutting edge, and

a rigid mounting protuberance extending axially rearwardly from the head base surface and having exactly two circumferentially spaced apart convex clamping surfaces,

wherein:

in a cross-section taken in a first horizontal plane perpendicular to the head axis and intersecting the mounting protuberance at the two clamping surfaces, only the two clamping surfaces are circumscribed by an imaginary first circle having a first diameter and a center coincident with the head axis.

Also, in accordance with the present invention, there is provided a rotary cutting tool comprising:

an elongated tool shank having a head receiving pocket at a forward end thereof and four shank flutes extending away from the forward end along a shank axis, and

5 a cutting head of the type described above releasably secured to the head 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
10 boundaries for partial views of a member and in which:

Fig. 1 is a perspective view of a cutting head in accordance with some embodiments of the present invention;

Fig. 2 is a side view of the cutting head shown in Fig. 1;

15 **Fig. 3** is a top view of the cutting head shown in Fig. 1;

Fig. 4 is a cross-sectional view of the cutting head shown in Fig. 2, taken along the line IV-IV;

Fig. 5 is a cross-sectional view of the cutting head shown in Fig. 2, taken along the line V-V;

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

Fig. 7 is a cross-sectional view of the cutting head shown in Fig. 3, taken along the line VII-VII;

25 **Fig. 8** is an exploded perspective view of a rotary cutting tool in accordance with some embodiments of the present invention;

Fig. 9 is an end view of a tool shank in accordance with some embodiments of the present invention;

Fig. 10 is a side view of the tool shank shown in Fig. 9;

30 **Fig. 11** is a cross-sectional view of the tool shank shown in Fig. 10, taken along the line XI-XI;

Fig. 12 is a side view of the rotary cutting tool shown in Fig. 8, in a state of clamped assembly;

Fig. 13 is a cross-sectional view of the rotary cutting tool shown in Fig. 12, taken along the line XIII-XIII;

5 **Fig. 14** is a side view of the rotary cutting tool shown in Fig. 8, in a state of unclamped assembly; and

Fig. 15 is a cross-sectional view of the rotary cutting tool shown in Fig. 14, taken along the line XV-XV.

10 DETAILED DESCRIPTION OF THE INVENTION

A first aspect of the present invention relates to a cutting head **20** rotatable about a head axis **AH** in a first direction of rotation **R1**, the head axis **AH** establishing an axial forward direction **DF** and an axial rearward direction **DR** opposite to the axial forward direction **DF**.

15 In some embodiments of the present invention, the cutting head **20** 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 to 3, the cutting head **20** comprises a cap portion **22** and a rigid mounting protuberance **24** joined to the cap portion **22**.

20 It should be appreciated that the cutting head **20** may be of unitary one-piece construction, and the mounting protuberance **24** may have the same rigidity as the cap portion **22** and be devoid of resiliently displaceable elements.

As seen below, the cap portion **22** has a first plurality of cutting portions **26**, being exactly twice the number of a second plurality of convex clamping surfaces **38** provided on the mounting protuberance **24**.

25 As shown in Figs. 1 to 3, the cap portion **22** has exactly four cutting portions **26** circumferentially alternating with four head flutes **28**, and a head base surface **30** facing in the axial rearward direction **DR**.

Also, as shown in Figs. 1 to 3, each cutting portion **26** has a front surface **32** facing in the axial forward direction **DF**, and each front surface **32** intersects a circumferentially adjacent and

rotationally forward head flute **28** with respect to the first direction of rotation **R1** to form a radially extending cutting edge **34**.

In some embodiments of the present invention, the four cutting edges **34** may be identical.

Also, in some embodiments of the present invention, the four cutting edges **34** may be
5 circumferentially equi-spaced about the head axis **AH**.

Further, in some embodiments of the present invention, apart from a pair of key slots **36** formed in two diametrically opposed cutting portions **26**, the cap portion **22** may exhibit 4-fold rotational symmetry about the head axis **AH**.

As shown in Fig. 3, the four cutting edges **34** may define a cutting diameter **DC**
10 corresponding to an imaginary cutting circle **CC**.

It should be appreciated throughout the description and claims, that the four radially outermost points of the four cutting edges **34** define the cutting diameter **DC** and lie on the imaginary cutting circle **CC**.

In some embodiments of the present invention, the cutting head **20** may be used for drilling
15 operations.

As shown in Figs. 1 to 3, the rigid mounting protuberance **24** extends axially rearwardly from the head base surface **30** and has exactly two circumferentially spaced apart convex clamping surfaces **38**.

In some embodiments of the present invention, a first vertical plane **PV1** containing the
20 head axis **AH** may intersect the two clamping surfaces **38**, and the two clamping surfaces **38** may be described as a pair of diametrically opposed clamping surfaces **38**.

Also, in some embodiments of the present invention, the two clamping surfaces **38** may be partially cylindrically shaped, and in a cross-section taken in the first vertical plane **PV1**, as shown in Fig. 4, the two clamping surfaces **38** may extend parallel to the head axis **AH**.

25 In other embodiments of the present invention (not shown), the two clamping surfaces **38** may be partially conically shaped, and in a cross-section taken in a vertical plane containing the head axis **AH** and intersecting the two clamping surfaces **38**, the two clamping surfaces **38** may diverge away from the head axis **AH** in the axial rearward direction **DR**. In other words, in the rearward direction of the mounting protuberance **24**, there is an increase in diameter size of an
30 imaginary circle circumscribing the two clamping surface **38**.

As shown in Figs. 1 and 2, the mounting protuberance **24** may have at least two circumferentially spaced apart axial stopper portions **39** located axially rearward of the two clamping surfaces **38**.

In some embodiments of the present invention, the first vertical plane **PV1** may intersect two of the at least two circumferentially spaced apart axial stopper portions **39**, and in the cross-section taken in the first vertical plane **PV1**, as shown in Fig. 4, the said two axial stopper portions **39** may extend radially beyond the two clamping surfaces **38**.

In some embodiments of the present invention, each axial stopper portion **39** may have a stopper surface **41** facing in the axial forward direction **DF**.

Also, in some embodiments of the present invention, the mounting protuberance **24** may have four axial stopper portions **39** circumferentially equi-spaced about the head axis **AH** forming a bulge **43** at the distal end thereof.

As shown in Fig. 5, in a cross-section taken in a first horizontal plane **PH1** perpendicular to the head axis **AH** and intersecting the mounting protuberance **24** at the two clamping surfaces **38**, according to the first aspect of the present invention, only the two clamping surfaces **38** are circumscribed by an imaginary first circle **C1** having a first diameter **D1** and a center coincident with the head axis **AH**.

Reverting to Fig. 4 and with reference to Fig. 5, each of the four axial stopper portions **39** extends radially outward of an axial projection of the first imaginary circle **C1**. In other words, an imaginary circle perpendicular to the head axis **AH** and having a center coincident therewith, and circumscribing the four axial stopper portions **39**, would have a diameter greater than the first diameter **D1**.

In some embodiments of the present invention, in the cross-section taken in the first horizontal plane **PH1**, no portion of the mounting protuberance **24** may be located outside the imaginary first circle **C1**, and it should be appreciated throughout the description and claims, that the imaginary first circle **C1** circumscribes the entire mounting protuberance **24** at only the two clamping surfaces **38**.

Also, in some embodiments of the present invention, in the cross-section taken in the first horizontal plane **PH1**, the two clamping surfaces **38** may form two clamping arcs **40** coincident with the imaginary first circle **C1**.

Further, in some embodiments of the present invention, the first vertical plane **PV1** may bisect the two clamping arcs **40** at midpoints thereof.

Yet further, in some embodiments of the present invention, the first vertical plane **PV1** may bisect the two clamping surfaces **38**.

5 As shown in Fig. 5, the first diameter **D1** may be less than forty percent of the cutting diameter **DC**, i.e., $D1 < 0.40 * DC$.

As shown in Fig. 6, in a cross-section taken in a second horizontal plane **PH2** perpendicular to the head axis **AH** and intersecting the cap portion **22**, the four head flutes **28** are inscribed by an imaginary second circle **C2** having a second diameter **D2** and a center coincident with the head axis **AH**, the imaginary second circle **C2** passing through four radially innermost head flute points **NH**, each head flute point **NH** associated with a corresponding one of the four head flutes **28**.
10

In some embodiments of the present invention, the second diameter **D2** may be greater than the first diameter **D1**, i.e., $D2 > D1$.

As shown in Figs. 1 to 3, the rigid mounting protuberance **24** may have two circumferentially spaced apart convex guide surfaces **42**, and the two guide surfaces **42** may circumferentially alternate with the two clamping surfaces **38**.
15

As shown in Fig. 5, in the cross-section taken in the first horizontal plane **PH1**, the two guide surfaces **42** may be located inside the imaginary first circle **C1**.

Also as shown in Fig. 5, in the cross-section taken in the first horizontal plane **PH1**, the two guide surfaces **42** may be circumscribed by an imaginary third circle **C3** having a third diameter **D3** and a center coincident with the head axis **AH**, and the third diameter **D3** may be less than the first diameter **D1**, but greater than eighty-five percent of the first diameter **D1**, i.e., $D1 > D3 > 0.85 * D1$.
20

It should be appreciated throughout the description and claims, that although the imaginary third circle **C3** circumscribes the two guide surfaces **42** in the cross-section taken in the first horizontal plane **PH1**, the imaginary third circle **C3** does not circumscribe the entire mounting protuberance **24**, especially the two clamping surfaces **38**.
25

As shown in Fig. 5, in the cross-section taken in the first horizontal plane **PH1**, the two guide surfaces **42** may form two guide arcs **37** coincident with the imaginary third circle **C3**.

In some embodiments of the present invention, a second vertical plane **PV2** containing the head axis **AH** may intersect the two guide surfaces **42**, and the two guide surfaces **42** may be described as a pair of diametrically opposed guide surfaces **42**.

Also, in some embodiments of the present invention, the second vertical plane **PV2** may bisect the two guide arcs **37** at midpoints thereof.

Further, in some embodiments of the present invention, the second vertical plane **PV2** may bisect the two guide surfaces **42**.

As shown in Fig. 5, the first and second vertical planes **PV1**, **PV2** may be mutually perpendicular.

In some embodiments of the present invention, the mounting protuberance **24** may exhibit 2-fold rotational symmetry about the head axis **AH**.

As shown in Figs. 1, 2 and 5, the rigid mounting protuberance **24** may have four transitional surfaces **45** circumferentially spaced apart by the two clamping surfaces **38** and the two guide surfaces **42**.

In some embodiments of the present invention, each transitional surface **45** may be planar.

Also, in some embodiments of the present invention, each transitional surface **45** may be parallel to the head axis **AH**.

As shown in Figs. 1 and 2, a rake surface **44** is disposed on each head flute **28** adjacent its associated cutting edge **34**.

As shown in Fig. 7, in a cross-section taken in a third vertical plane **PV3** parallel to the head axis **AH** and transverse to one of the cutting edges **34** along at least a radially outer portion thereof, the rake surface **44** may be inclined at a positive rake angle α_1 .

It should be appreciated throughout the description and claims, that the term "positive rake angle" refers to an acute external angle formed between the rake surface **44** and an imaginary reference line parallel to the head axis **AH** and intersecting the associated cutting edge **34**.

In some embodiments of the present invention, the rake angle α_1 may be greater than seven degrees, i.e., $\alpha_1 > 7^\circ$.

As shown in Figs. 1 and 5, the head base surface **30** includes a central base region **46** and four radially outer base regions **48**, and each head flute **28** intersects one of the four radially outer base regions **48** to form a radially outer base edge **50**.

As shown in Fig. 5, the central base region **46** may entirely surround the mounting protuberance **24**.

In some embodiments of the present invention, the four radially outer base regions **48** and the central base region **46** may be coplanar.

5 As shown in Fig. 5, the third vertical plane **PV3** intersects one of the radially outer base edges **50**.

In some embodiments of the present invention, as shown in Figs. 1 and 5, a joining surface **52** may be disposed on each head flute **28** adjacent its associated radially outer base edge **50**.

10 As shown in Fig. 7, in the cross-section taken in the third vertical plane **PV3**, a straight tangent line **LT** tangential to the joining surface **52** may be inclined at a zero or positive joining angle $\beta 1$.

It should be appreciated throughout the description and claims, that the term "zero joining angle" refers to a configuration in which the straight tangent line **LT** is parallel to the head axis **AH**, and the term "positive joining angle" refers to an acute internal angle formed between the
15 straight tangent line **LT** and an imaginary reference line parallel to the head axis **AH** and intersecting the associated radially outer base edge **50**.

In some embodiments of the present invention, the joining angle $\beta 1$ may be less than the rake angle $\alpha 1$, i.e., $\beta 1 < \alpha 1$.

20 For embodiments of the present invention in which the joining angle $\beta 1$ is less than the rake angle $\alpha 1$, it should be appreciated that in the cross-section taken in the third vertical plane **PV3**, as shown in Fig. 7, the joining surface **52** may be concave.

Also, for embodiments of the present invention in which the joining angle $\beta 1$ is less than the rake angle $\alpha 1$, it should be appreciated that the surface area of each of the four radially outer base regions **48** may be advantageously increased, whilst providing each of the four head flutes **28**
25 with an optimally large flute volume.

For such embodiments, it should be appreciated that the increased surface area of each radially outer base region **48** contributes to providing a cutting tool with good stability when the cutting head **20** is releasably secured to a tool shank, and providing each head flute **28** with an optimally large flute volume is of greater importance when the cutting head **20** is configured with
30 four circumferentially spaced apart head flutes **28**, compared to an alternative cutting head

configuration (not shown), having, for example, only two or three circumferentially spaced apart head flutes.

As shown in Figs. 1 to 3, each cutting portion **26** may have a torque transmission surface **54** facing opposite the first direction of rotation **R1**.

For embodiments of the present invention in which each cutting portion **26** has a torque transmission surface **54**, and the cap portion **22** substantially exhibits 4-fold rotational symmetry about the head axis **AH**, it should be appreciated that the cutting head **20** may be mounted on a tool shank in four index positions whereby each of the four torque transmission surfaces **54** makes contact with a different one of four shank drive surfaces, the four torque transmission surfaces **54** and four index positions being exactly twice the number of the second plurality of convex clamping surfaces **38** provided on the mounting protuberance **24**.

In some embodiments of the present invention, each torque transmission surface **54** may be located between its associated cutting portion's front surface **32** and one of the radially outer base regions **48**.

Also, in some embodiments of the present invention, each torque transmission surface **54** may be planar.

Further, in some embodiments of the present invention, as shown in Fig. 2, each torque transmission surface **54** may be inclined in the first direction of rotation **R1** as it extends in the axial rearward direction **DR** away from its associated cutting portion's front surface **32**.

As shown in Figs. 8 to 13, a second aspect of the present invention relates to a rotary cutting tool **56** having the cutting head **20** secured to an elongated tool shank **58**. The tool shank **58** is provided with a head receiving pocket **60** at a forward end **62** thereof and four shank flutes **64** extending away from the forward end **62** along a shank axis **AS**, and the cutting head **20** is releasably secured to the head receiving pocket **60**.

In some embodiments the cutting head **20** may be releasably secured to the head receiving pocket **60** without the requirement of an additional fastening member, such as a clamping screw.

It should be appreciated throughout the description and claims, that when the cutting head **20** is releasably secured to the head receiving pocket **60**, and the rotary cutting tool **56** is in a state of assembly, the four shank flutes **64** extend away from the tool shank's forward end **62** in the axial rearward direction **DR**.

As shown in Figs. 8 to 10, the four shank flutes **64** may be formed in a cylindrical shank peripheral surface **65** of the tool shank **58**.

In some embodiments of the present invention, the head axis **AH** may be coincident with the shank axis **AS**.

5 Also, in some embodiments of the present invention, the four shank flutes **64** may helically extend along the shank axis **AS**, and the four head flutes **28** may serve as corresponding extensions of the four shank flutes **64**.

Further, in some embodiments of the present invention, the tool shank **58** may preferably be manufactured from tool steel.

10 Yet further, in some embodiments of the present invention, the rotary cutting tool **56** may be used for drilling operations.

As shown in Figs. 8 and 9, the head receiving pocket **60** has a shank support surface **66** transverse to the shank axis **AS** and a central recess **68** formed in the shank support surface **66**.

15 In some embodiments of the present invention, the central recess **68** may not intersect any of the four shank flutes **64**.

As shown in Fig. 9, the shank support surface **66** includes a central support region **70** and four radially outer support regions **72**.

In some embodiments of the present invention, the central recess **68** may be formed in the central support region **70**.

20 Also, in some embodiments of the present invention, each radially outer support region **72** may intersect the shank peripheral surface **65**.

Further, in some embodiments of the present invention, the four radially outer support regions **72** may be coplanar and located axially forward of the central support region **70**.

25 As shown in Figs. 9 and 11, the central recess **68** has four circumferentially spaced apart resiliently displaceable abutment portions **74**, each abutment portion **74** having a radially inward facing abutment surface **76**.

In some embodiments of the present invention, the four abutment portions **74** may be identical, and the four abutment surfaces **76** may be arranged as two pairs of diametrically opposed abutment surfaces **76**. Thus, the tool shank **58** has a third plurality of abutment surfaces **76**, being

the same in number as the first plurality of cutting portions **26** and exactly twice the number of the second plurality of convex clamping surfaces **38**.

In some embodiments of the present invention, the four abutment portions **74** may be independently resiliently displaceable, and for such embodiments it should be appreciated that radial displacement of one of the four abutment portions **74** does not cause radial displacement of any of the other three abutment portions **74**.

Also, in some embodiments of the present invention, the central recess **68** may include four intermediate portions **78** which circumferentially alternate with the four abutment portions **74**, and each intermediate portion **78** may have an intermediate surface **80** intersecting two circumferentially adjacent abutment surfaces **76**.

Further, in some embodiments of the present invention, each intermediate surface **80** may extend radially outwardly from the two circumferentially adjacent abutment surfaces **76**.

For embodiments of the present invention in which the four abutment surfaces **76** circumferentially alternate with the four intermediate surfaces **80**, the head receiving pocket **60** has a 'circumferentially confined' central recess **68**, which improves the resilience of the four abutment portions **74** and extends the useful life of the tool shank **58**.

As shown in Figs. 9 and 11, prior to the cutting head **20** being releasably secured to the head receiving pocket **60**, the head receiving pocket **60** may exhibit 4-fold rotational symmetry about the shank axis **AS**.

Also, prior to the cutting head **20** being releasably secured to the head receiving pocket **60**, the tool shank **58** may exhibit 4-fold rotational symmetry about the shank axis **AS**.

According to the second aspect of the present invention, as shown in Figs. 12 and 13, the mounting protuberance **24** is resiliently retained in the central recess **68** in any one of four index positions, and in each index position:

the head base surface **30** faces the shank support surface **66**,

the two clamping surfaces **38** make clamping contact with two operative abutment surfaces **76'** of the four abutment surfaces **76**, and

no clamping contact occurs between the rigid mounting protuberance **24** and two non-operative abutment surfaces **76''** of the four abutment surfaces **76**.

It should be appreciated throughout the description and claims, that clamping contact between the two clamping surfaces **38** and the two operative abutment surfaces **76'** results in radial outward displacement of the two associated abutment portions **74**.

It should also be appreciated throughout the description and claims, that no clamping contact occurs between the rigid mounting protuberance **24** and the two non-operative abutment surfaces **76''**, and the mounting protuberance's two guide surfaces **42** may face the two non-operative abutment surfaces **76''** with minimal spacing therebetween.

In some embodiments of the present invention, in each index position, the head receiving pocket **60** may exhibit 2-fold rotational symmetry about the shank axis **AS**.

It should be appreciated that the rotary cutting tool's tool shank **58** has two operational configurations, namely, a first operational configuration in which the mounting protuberance **24** of a removably secured cutting head **20** is resiliently retained in the tool shank's central recess **68** in a first or second of the above said four index positions in which a same first pair of diametrically opposed abutment surfaces **76** are operative, and a second operational configuration in which the mounting protuberance **24** of a removably secured cutting head **20** is resiliently retained in the tool shank's central recess **68** in a third or fourth of the above said four index positions in which a same second pair of diametrically opposed abutment surfaces **76** are operative.

In the present rotary cutting tool **56**, the tool shank **58** has exactly twice as many radially inward facing abutment surfaces **76** in its central recess **68**, as the cutting head **20** has clamping surfaces **38** on its mounting protuberance **24**. Thus, in the fully assembled rotary cutting tool **56**, in the circumferential direction of the tool shank's central recess **68**, only alternate ones of the third plurality of abutment surfaces **76** are operative. More specifically, the second plurality of circumferentially spaced apart convex clamping surfaces **38** on the cutting head's mounting protuberance **24** are in abutment with alternate ones of the third plurality of circumferentially spaced apart and radially inward facing abutment surfaces **76** of the tool shank's central recess **68**.

It should also be appreciated that by having two operational configurations, the useful life of the rotary cutting tool's tool shank **58** may be advantageously extended.

It should further be appreciated that visual markings or indications (not shown) may be provided on the tool shank's forward end **62** to enable the first and second pairs of diametrically opposed abutment surfaces **76** to be distinguished from each other.

It should yet further be appreciated that the key slots **36** located on the cutting head's cap portion **22**, may provide a visual indication for the position of the two clamping surfaces **38** on the cutting head's mounting protuberance **24**, which may be relied upon when selecting the desired index position of the cutting head **20** in the tool shank's central recess **68**.

5 For embodiments of the present invention in which the four abutment portions **74** are independently resiliently displaceable, it should be appreciated that the useful life of the rotary cutting tool's tool shank **58** may be doubled.

It should further be appreciated that during the useful life of each of the tool shank's first and second operational configurations, several cutting heads **20** may be releasably secured to the tool shank's head receiving pocket **60** and used in drilling operations before being replaced after wear.

10 As shown in Figs. 12 and 13, when the cutting head **20** is releasably secured to the head receiving pocket **60**, and the rotary cutting tool **56** is in a state of clamped assembly, the head base surface **30** may make contact with the shank support surface **66**, and apart from the two clamping surfaces **38** making clamping contact with the two operative abutment surfaces **76'**, no other portion of the mounting protuberance **24** may make clamping contact with the central recess **68**.

In some embodiments of the present invention, at least three of the four radially outer base regions **48** may make contact with at least three of the four radially outer support regions **72**.

20 It should be appreciated that during drilling operations, axially rearward cutting forces will typically overcome any inaccuracies associated with the coplanarity of the four radially outer support regions **72**, resulting in contact between all four radially outer base regions **48** and all four radially outer support regions **72**.

Also, in some embodiments of the present invention, the central base region **46** may be spaced apart from the central support region **70**.

25 As shown in Fig. 13, in a cross-section taken in a third horizontal plane **PH3** perpendicular to the shank axis **AS** and passing through the central recess **68**, an imaginary fourth circle **C4** having a fourth diameter **D4** and a center coincident with the shank axis **AS** inscribes the two operative abutment surfaces **76'**, while an imaginary fifth circle **C5** having a fifth diameter **D5** and a center coincident with the shank axis **AS** inscribes the two non-operative abutment surfaces **76''**,
30 and the fourth diameter **D4** is greater than the fifth diameter **D5**, i.e., $D4 > D5$.

It should be appreciated throughout the description and claims, that in the cross-section taken in the third horizontal plane **PH3**, none of central recess's four abutment portions **74** and four intermediate portions **78** may traverse the imaginary fifth circle **C5**.

5 In some embodiments of the present invention, the first and third horizontal planes **PH1**, **PH3** may be coincident, and the first diameter **D1** may be greater than the fifth diameter **D5**, i.e., $D1 > D5$.

Also, for embodiments of the present invention in which the first and third horizontal planes **PH1**, **PH3** are coincident, the first diameter **D1** may be equal to the fourth diameter **D4**, i.e., $D1 = D4$. Restated, the diameter of the outermost portions of the clamping surfaces **38** matches
10 that of the operative abutment surfaces **76'**.

Further, for embodiments of the present invention in which the first and third horizontal planes **PH1**, **PH3** are coincident, the third diameter **D3** may be less than the fifth diameter **D5**, i.e., $D3 < D5$. Restated, the diameter of the outermost portions of the guide surfaces **42** is less than that of the non-operative abutment surfaces **76''**.

15 For embodiments of the present invention in which the four circumferentially spaced apart resiliently displaceable abutment portions **74** are identical, it should be appreciated that prior to the cutting head **20** being releasably secured to the head receiving pocket **60**, as shown in Fig. 11, in the cross-section taken in the third horizontal plane **PH3**, the imaginary fifth circle **C5** inscribes all of the four abutment surfaces **76**.

20 Also, for embodiments of the present invention in which the four circumferentially spaced apart resiliently displaceable abutment portions **74** are identical, it should be appreciated that prior to the cutting head **20** being releasably secured to the head receiving pocket **60**, as shown in Fig. 11, in the cross-section taken in the third horizontal plane **PH3**, the four shank flutes **64** are inscribed by an imaginary sixth circle **C6** having a sixth diameter **D6** and a center coincident with
25 the shank axis **AS** at four first flute points **Nf1**.

In some embodiments of the present invention, a radial flute axis **AF** perpendicular to the shank axis **AS** and containing one of the four first flute points **Nf1** may intersect one of the four abutment surfaces **76**, and each first flute point **Nf1** may be located a minimum first wall thickness **T1** from its adjacent abutment surface **76** along its associated radial flute axis **AF**.

Also, in some embodiments of the present invention, the sixth diameter **D6** may be between ninety percent and one hundred and ten percent of the second diameter **D2**, i.e. $D2 \cdot 0.90 < D6 < D2 \cdot 1.10$.

As shown in Fig. 11, in the cross-section taken in the third horizontal plane **PH3**, prior to the cutting head **20** being releasably secured to the head receiving pocket **60**, each shank flute **64** has a second flute point **Nf2** spaced apart from the first flute point **Nf1** and located a minimum second wall thickness **T2** from its adjacent intermediate surface **80**.

In some embodiments of the present invention, the minimum second wall thickness **T2** may be equal to or less than the minimum first wall thickness **T1**, i.e. $T2 < T1$.

For embodiments of the present invention in which the minimum second wall thickness **T2** is equal to or less than the minimum first wall thickness **T1**, it should be appreciated that the close proximity of each shank flute **64** to its adjacent intermediate surface **80** is a main parameter for regulating the resilience of the associated abutment portion **74**.

As shown in Figs. 8 to 10, the tool shank's forward end **62** may have four drive protuberances **82** protruding from the shank support surface **66**, and each drive protuberance **82** may have a drive surface **84** adjacent one of the radially outer support regions **72** facing in the first direction of rotation **R1**.

In some embodiments of the present invention, each drive surface **84** may intersect the shank peripheral surface **65**.

When the cutting head **20** is releasably secured to the head receiving pocket **60**, and the rotary cutting tool **56** is in a state of clamped assembly, as shown in Fig. 12, at least two of the four drive surfaces **84** may make contact with at least two of the four torque transmission surfaces **54**.

By virtue of clamping contact occurring between the two clamping surfaces **38** and the two operative abutment surfaces **76'** and no clamping contact between the rigid mounting protuberance **24** and the two non-operative abutment surfaces **76''**, it should be appreciated that the tool shank's forward end **62** may undergo very slight torsional twisting, which may result in only two diametrically opposed drive surfaces **84** of the four drive surfaces **84** making contact with two diametrically opposed torque transmission surfaces **54** of the four torque transmission surfaces **54**, although during drilling operations, rotational cutting forces will typically overcome the said slight

torsional twisting, resulting in contact between all four drive surfaces **84** and all four torque transmission surfaces **54**.

In some embodiments of the present invention, the four drive surfaces **84** and the four torque transmission surfaces **54** may be correspondingly inclined with respect to the first direction of rotation **R1**.

By configuring each drive surface **84** to be slanted away from the first direction of rotation **R1** as it extends away from its associated radially outer support region **72**, as shown in Fig. 12, it should be appreciated that a component of the rotational cutting forces is directed axially rearwardly and the robustness of the four drive protuberances **82** is increased.

The present invention further relates to a method of assembling the rotary cutting tool **56**, comprising the steps of:

- a) orienting the head base surface **30** to face the shank support surface **66**;
- b) aligning the head axis **AH** with the shank axis **AS**;
- c) rotationally aligning the two clamping surfaces **38** with two of the four intermediate portions **78**;
- d) inserting the mounting protuberance **24** into the central recess **68**, until the head base surface **30** makes contact with the shank support surface **66**, as shown in Fig. 14; and
- e) rotating the cutting head **20** about its head axis **AH** opposite the first direction of rotation **R1**, until the two clamping surfaces **38** are resiliently retained against two operative abutment surfaces **76'** of the four abutment surfaces **76**, as shown in Fig. 12.

In some embodiments of the present invention, in step d), the rotary cutting tool **56** is in a state of unclamped assembly whereby none of the four abutment portions **74** are being resiliently displaced, and in the cross-section taken in the third horizontal plane **PH3**, as shown in Fig. 15, an imaginary seventh circle **C7** having a seventh diameter **D7** and a center coincident with the shank axis **AS** may inscribe all of the four abutment surfaces **76**.

For embodiments of the present invention in which the first and third horizontal planes **PH1**, **PH3** are coincident, the first diameter **D1** may be greater than the seventh diameter **D7**, i.e., $D1 > D7$, although due to the two clamping surfaces **38** being rotationally aligned with two of the four intermediate portions **78**, no radially outward forces **FR** are being applied to any of the four

abutment portions **74** and the head receiving pocket **60** has a configuration identical to that prior to the cutting head **20** being releasably secured thereto.

Also, in some embodiments of the present invention, in step d), the head receiving pocket **60** may exhibit 4-fold rotational symmetry about the shank axis **AS**.

5 It should be appreciated that step e) is typically performed by using an assembly tool (not shown) which engages the cutting head's key slots **36**.

In some embodiments of the present invention, in step e), the cutting head **20** may be rotated by approximately 45 degrees about its head axis **AH** relative to the tool shank's central recess **68**, until the rotary cutting tool **56** achieves a state of clamped assembly.

10 It should also be appreciated that step e) is typically performed until at least two of the four drive surfaces **84** make contact with at least two of the four torque transmission surfaces **54**.

Also, in some embodiments of the present invention, in step e), the two abutment portions **74** associated with the two operative abutment surfaces **76'** are being resiliently displaced, and in the cross-section taken in the third horizontal plane **PH3**, as shown in Fig. 13, the imaginary fourth circle **C4** inscribes the two operative abutment surfaces **76'** and the fourth diameter **D4** is greater than the seventh diameter **D7**, i.e., $D4 > D7$.

It should further be appreciated in step e), that radially outward forces **FR** are being applied to the said two abutment portions **74** associated with the two operative abutment surfaces **76'** by the two clamping surfaces **38**.

20 Further, in some embodiments of the present invention, in step e), the two abutment portions **74** associated with the two non-operative abutment surfaces **76''** are not being resiliently displaced, and in the cross-section taken in the third horizontal plane **PH3**, as shown in Fig. 13, the imaginary fifth circle **C5** inscribes the two non-operative abutment surfaces **76''** and the fifth diameter **D5** is equal to the seventh diameter **D7**, i.e., $D5 = D7$.

25 It should yet further be appreciated in step e), that no radially outward forces **FR** are being applied to the said two abutment portions **74** associated with the two non-operative abutment surfaces **76''**.

Yet further, in some embodiments of the present invention, in step e), the head receiving pocket **60** may exhibit 2-fold rotational symmetry about the shank axis **AS**.

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 scope of the invention as hereinafter claimed.

CLAIMS

5

What is claimed is:

1. A cutting head (20) rotatable about a head axis (AH) in a first direction of rotation (R1), the head axis (AH) establishing an axial forward direction (DF) and an axial rearward direction (DF) opposite the axial forward direction (DF), the cutting head comprising:
- 10 a cap portion (22) having exactly four cutting portions (26) circumferentially alternating with four head flutes (28), and a head base surface (30) facing in the axial rearward direction (DR),
- each cutting portion (26) having a front surface (32) facing in the axial forward direction (DF) and intersecting a circumferentially adjacent and rotationally forward head flute (28) with respect to the first direction of rotation
- 15 (R1) to form a radially extending cutting edge (34), and
- a rigid mounting protuberance (24) extending axially rearwardly from the head base surface (30) and having exactly two circumferentially spaced apart convex clamping surfaces (38), wherein:
- 20 in a cross-section taken in a first horizontal plane (PH1) perpendicular to the head axis (AH) and intersecting the mounting protuberance (24) at the two clamping surfaces (38), only the two clamping surfaces (38) are circumscribed by an imaginary first circle (C1) having a first diameter (D1) and a center coincident with the head axis (AH).
- 25 2. The cutting head (20) according to claim 1, wherein:
- the four cutting edges (34) are identical.
3. The cutting head (20) according to claim 1 or 2, wherein:
- the four cutting edges (34) are circumferentially equi-spaced about the head axis (AH).
- 30 4. The cutting head (20) according to any one of the preceding claims, wherein:

the mounting protuberance (34) exhibits 2-fold rotational symmetry about the head axis (AH).

5 **5.** The cutting head (20) according to any one of the preceding claims, wherein, in the cross-section taken in the first horizontal plane (PH1):

the two clamping surfaces (38) form two clamping arcs (40) coincident with the imaginary first circle (C1).

10 **6.** The cutting head (20) according to any one of the preceding claims, wherein:

each cutting portion (26) has a torque transmission surface (54) facing opposite the first direction of rotation (R1).

15 **7.** The cutting head (20) according to any one of the preceding claims, wherein:

the rigid mounting protuberance (24) has two circumferentially spaced apart convex guide surfaces (42),

the two guide surfaces (42) circumferentially alternate with the two clamping surfaces (38), and

in the cross-section taken in the first horizontal plane (PH1), the two guide surfaces (42) are located inside the imaginary first circle (C1).

20 **8.** The cutting head (20) according to claim 7, wherein, in the cross-section taken in the first horizontal plane (PH1):

the two guide surfaces (42) are circumscribed by an imaginary third circle (C3) having a third diameter (D3) and a center coincident with the head axis (AH), and

25 the third diameter (D3) is less than the first diameter (D1), but greater than eighty-five percent of the first diameter (D1).

9. The cutting head (20) according to claim 8, wherein, in the cross-section taken in the first horizontal plane (PH1):

the two guide surfaces (42) form two guide arcs (37) coincident with the imaginary third circle (C3).

10. The cutting head (20) according to any one of the preceding claims, wherein:

the mounting protuberance (24) has four circumferentially spaced apart axial stopper portions (39) located axially rearward of the two clamping surfaces (38), and

each of the four axial stopper portions (39) extends radially outward of an axial projection of the first imaginary circle (C1) circumscribing the two clamping surfaces (38).

11. The cutting head (20) according to any one of the preceding claims, wherein, in a cross-section taken in a second horizontal plane (PH2) perpendicular to the head axis (AH) and intersecting the cap portion (22):

the four head flutes (28) are inscribed by an imaginary second circle (C2) having a second diameter (D2) and a center coincident with the head axis (AH), the imaginary second circle (C2) passing through four radially innermost head flute points (NH), each head flute point (NH) associated with a corresponding one of the four head flutes (28), and

the second diameter (D2) is greater than the first diameter (D1).

12. The cutting head (20) according to any one of the preceding claims, wherein:

the four cutting edges (34) define a cutting diameter (DC) corresponding to a cutting circle (CC),

the first diameter (D1) is less than forty percent of the cutting diameter (DC).

13. The cutting head (20) according to any one of the preceding claims, wherein:

a rake surface (44) is disposed on each head flute (28) adjacent its associated cutting edge (34), and

in a cross-section taken in a third vertical plane (PV3) parallel to the head axis (AH) and transverse to one of the cutting edges (34) along at least a radially outer portion thereof, the rake surface (44) is inclined at a positive rake angle (α_1).

14. The cutting head (20) according to claim 13, wherein:
the head base surface (30) includes a central base region (46) and four radially outer base regions (48),
each head flute (28) intersects one of the four radially outer base regions (48) to form a
5 radially outer base edge (50), and
the third vertical plane (PV3) intersects one of the radially outer base edges (50).

15. The cutting head (20) according to claim 14, wherein:
a joining surface (52) is disposed on each head flute (28) adjacent its associated radially
10 outer base edge (50),
in the cross-section taken in the third vertical plane (PV3), a straight tangent line (LT) tangential to the joining surface (52) is inclined at a zero or positive joining angle (β_1), and
the joining angle (β_1) is less than the rake angle (α_1).

15 16. A rotary cutting tool (56) comprising:
an elongated tool shank (58) having a head receiving pocket (60) at a forward end (62) thereof and four shank flutes (64) extending away from the forward end (62) along a shank axis (AS), and
the cutting head (20) according to any one of the preceding claims releasably secured to
20 the head receiving pocket (60).

17. The rotary cutting tool (56) according to claim 16, wherein:
the head receiving pocket (60) has a shank support surface (66) transverse to the shank axis (AS) and a central recess (68) formed in the shank support surface (66),
25 the central recess (68) has four circumferentially spaced apart resiliently displaceable abutment portions (74), each abutment portion (74) having a radially inward facing abutment surface (76),
the mounting protuberance (24) is resiliently retained in the central recess (68) in any one of four index positions, and
30 in each index position:

the head base surface (30) faces the shank support surface (66),
the two clamping surfaces (38) make clamping contact with two operative abutment surfaces (76') of the four abutment surfaces (76), and
no clamping contact occurs between the rigid mounting protuberance (24) and two non-operative abutment surfaces (76'') of the four abutment surfaces (76).

18. The rotary cutting tool (56) according to claim 17, wherein:
the four abutment portions (74) are independently resiliently displaceable.

19. The rotary cutting tool (56) according to claim 17 or 18, wherein:
the rigid mounting protuberance (24) has two circumferentially spaced apart convex guide surfaces (42),
the two guide surfaces (42) circumferentially alternate with the two clamping surfaces (38),
in the cross-section taken in the first horizontal plane (PH1), the two guide surfaces (42) are located inside the imaginary first circle (C1), and
the two guide surfaces (42) face the two non-operative abutment surfaces (76').

20. The rotary cutting tool (56) according to any one of claims 17 to 19, wherein:
the head base surface (30) makes contact with the shank support surface (66), and
apart from the two clamping surfaces (38) making clamping contact with the two operative abutment surfaces (76'), no other portion of the mounting protuberance (24) makes clamping contact with the central recess (68).

21. The rotary cutting tool (56) according to claim 20, wherein:
the head base surface (30) includes a central base region (46) and four radially outer base regions (48),
the shank support surface (66) includes a central support region (70) and four radially outer support regions (72), and
at least three of the four radially outer base regions (48) make contact with at least three of the four radially outer support regions (72).

22. The rotary cutting tool (56) according to any one of claims 17 to 21, wherein, in a cross-section taken in a third horizontal plane (PH3) perpendicular to the shank axis (AS) and passing through the central recess (68):

5 an imaginary fourth circle (C4) having a fourth diameter (D4) and a center coincident with the shank axis (AS) inscribes the two operative abutment surfaces (76"),

 an imaginary fifth circle (C5) having a fifth diameter (D5) and a center coincident with the shank axis (AS) inscribes the two non-operative abutment surfaces (76"), and

 the fourth diameter (D4) is greater than the fifth diameter (D5).

10 **23.** The rotary cutting tool (56) according to claim 22, wherein:

 the first and third horizontal planes (PH1, PH3) are coincident, and

 the first diameter (D1) is greater than the fifth diameter (D5).

15 **24.** The rotary cutting tool (56) according to claim 22 or 23, wherein:

 the first and third horizontal planes (PH1, PH3) are coincident, and

 the first diameter (D1) is equal to the fourth diameter (D4).

20 **25.** A method of assembling the rotary cutting tool (56) according to any one of claims 17 to 24,

 wherein the central recess (68) further comprises four intermediate portions (78) which circumferentially alternate with the four abutment portions (74); and

 the method comprises:

25 a) orienting the head base surface (30) to face the shank support surface (66);

 b) aligning the head axis (AH) with the shank axis (AS);

 c) rotationally aligning the two clamping surfaces (38) with two of the four intermediate portions (78);

 d) inserting the mounting protuberance (24) into the central recess (68), until the head base surface (30) makes contact with the shank support surface (66); and

- e) rotating the cutting head (20) about its head axis (AH) opposite the first direction of rotation (R1), until the two clamping surfaces (38) are resiliently retained against two operative abutment surfaces (76') of the four abutment surfaces (76).

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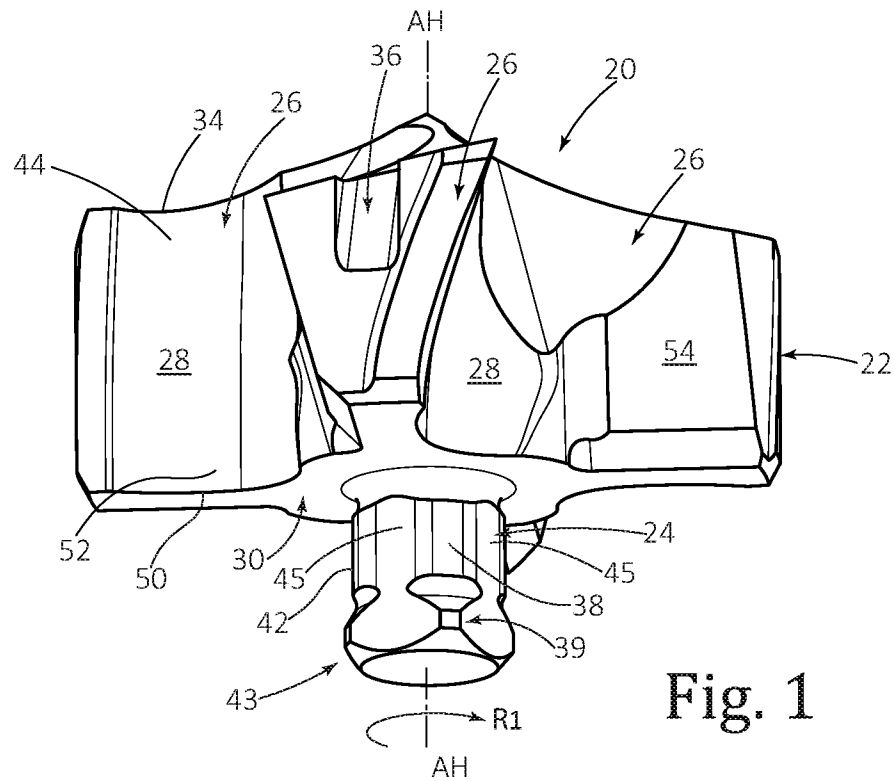


Fig. 1

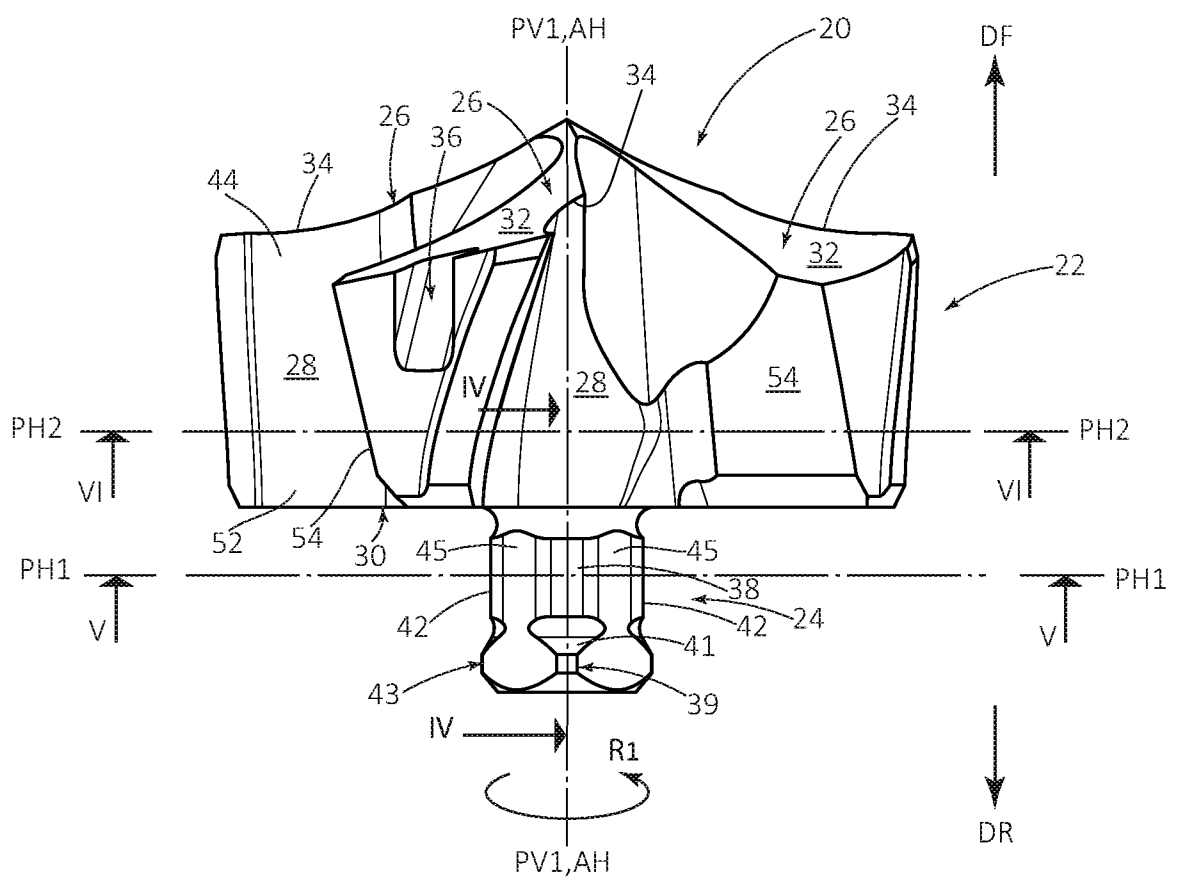


Fig. 2

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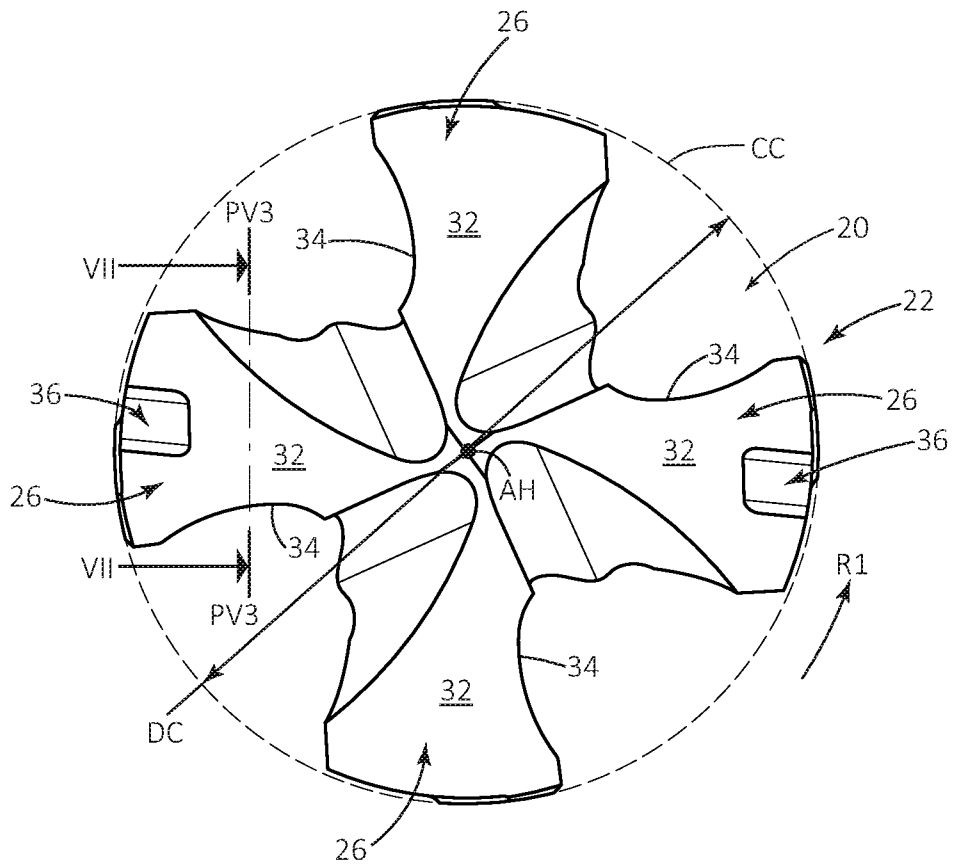


Fig. 3

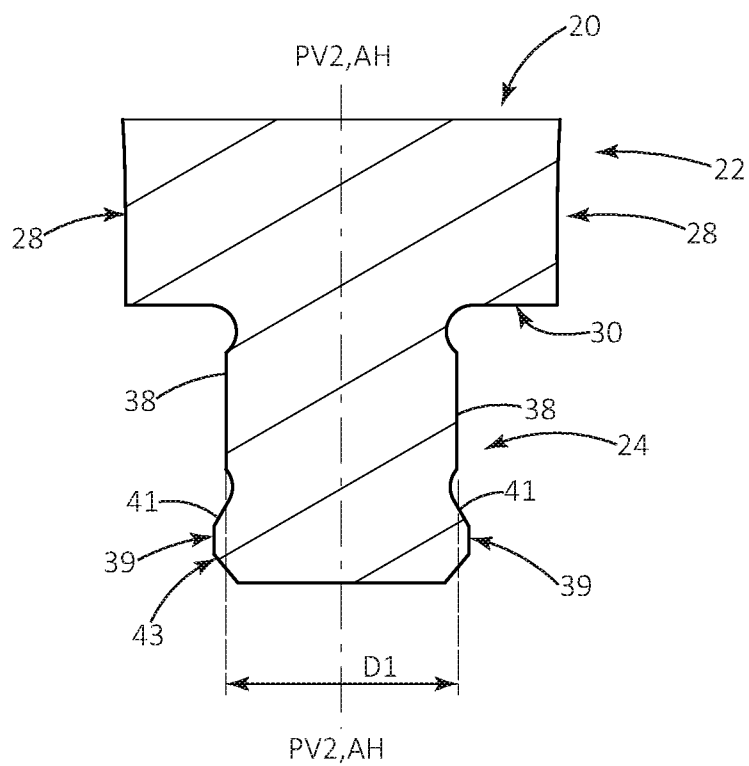


Fig. 4

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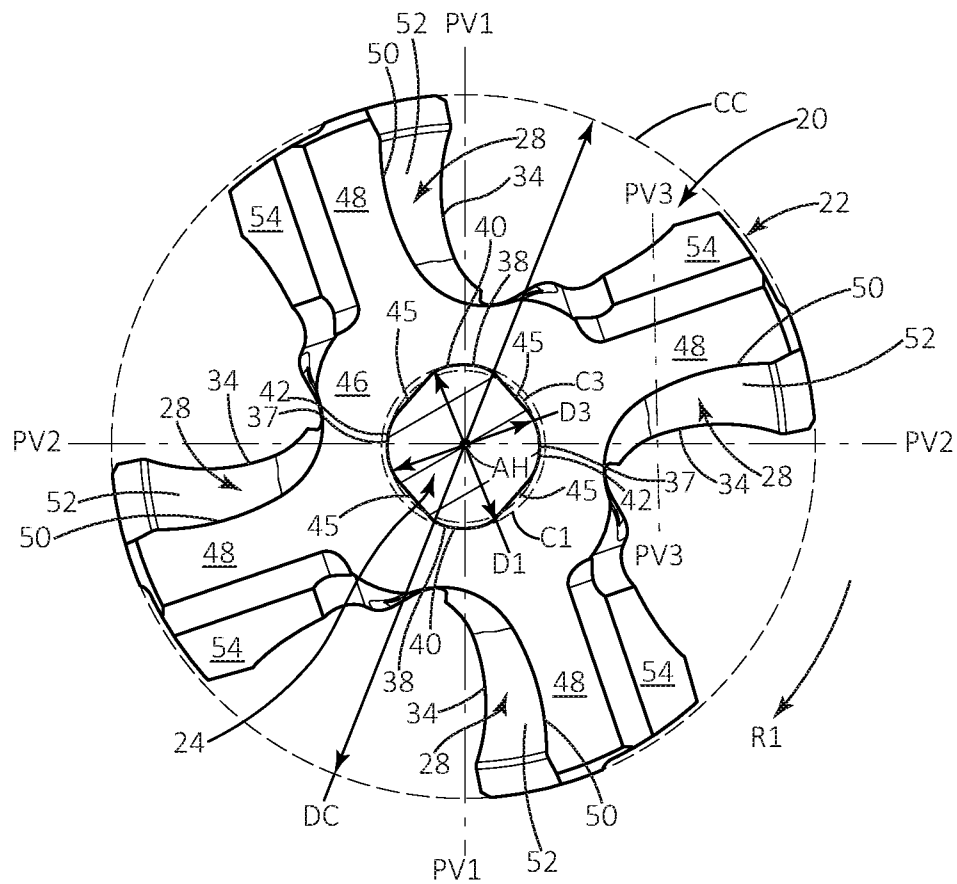


Fig. 5

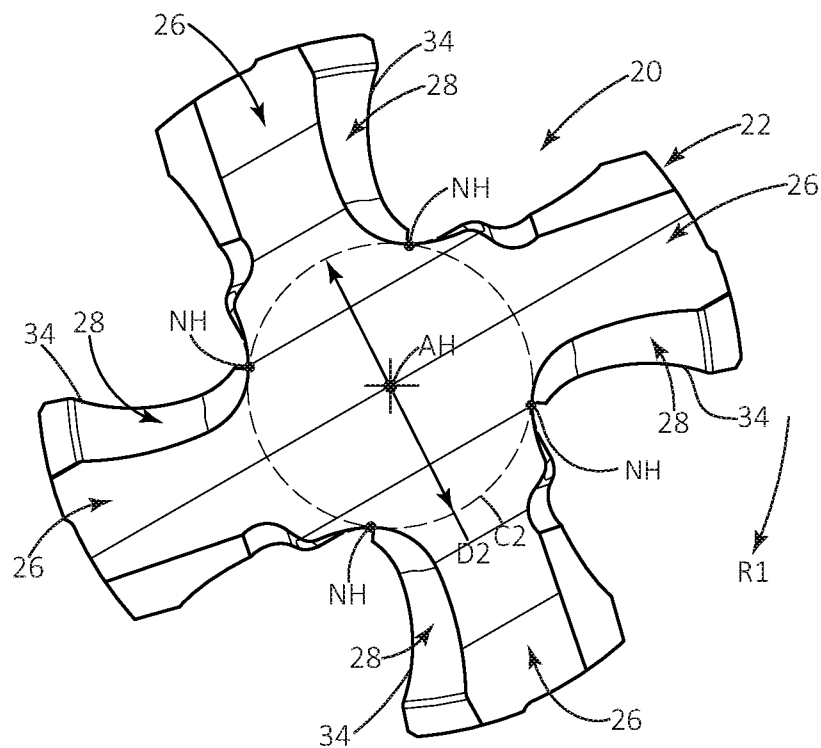


Fig. 6

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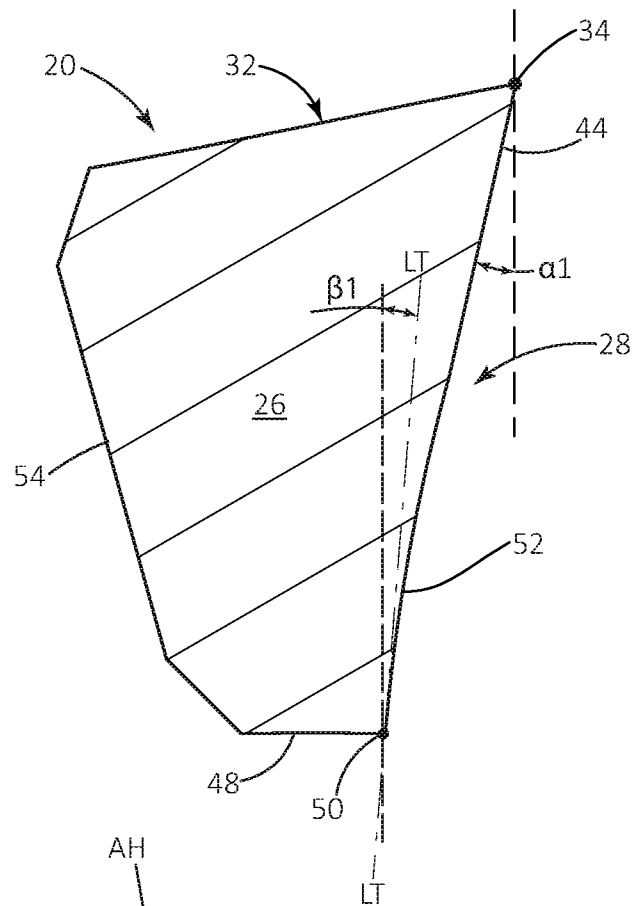


Fig. 7

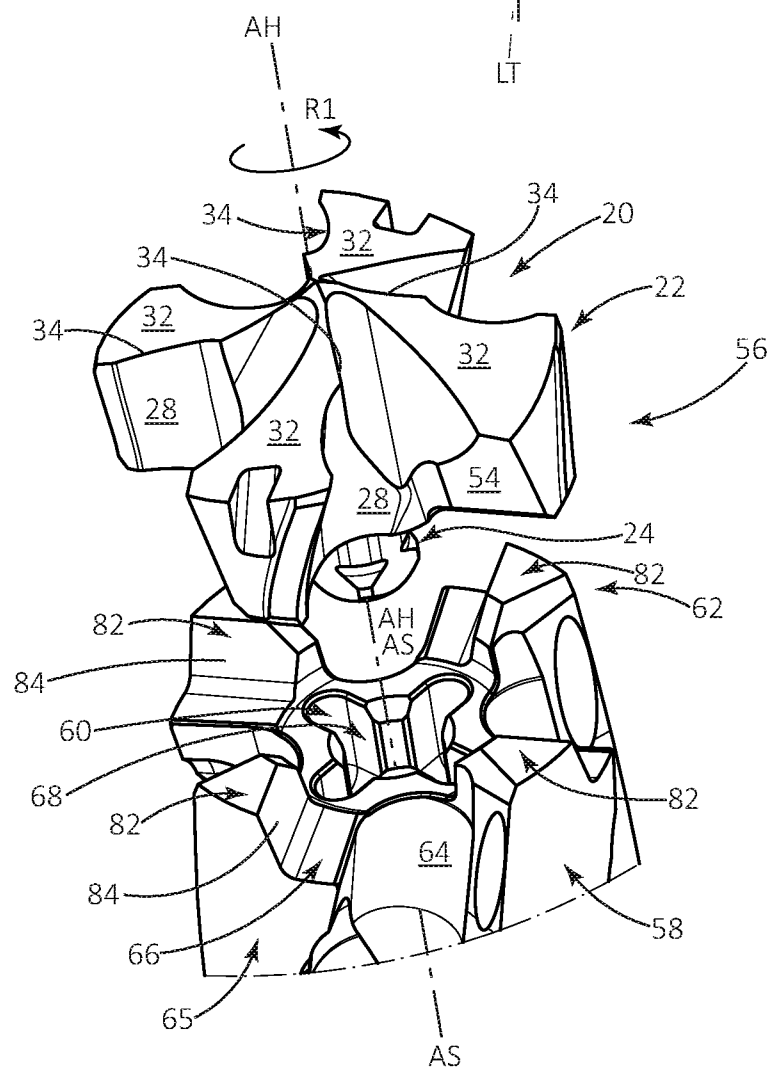


Fig. 8

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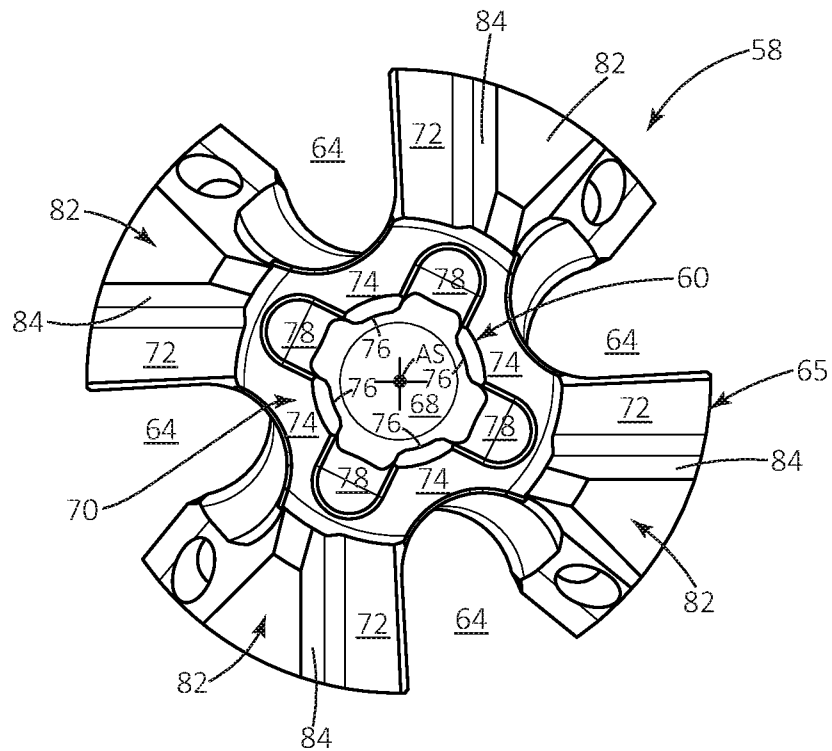


Fig. 9

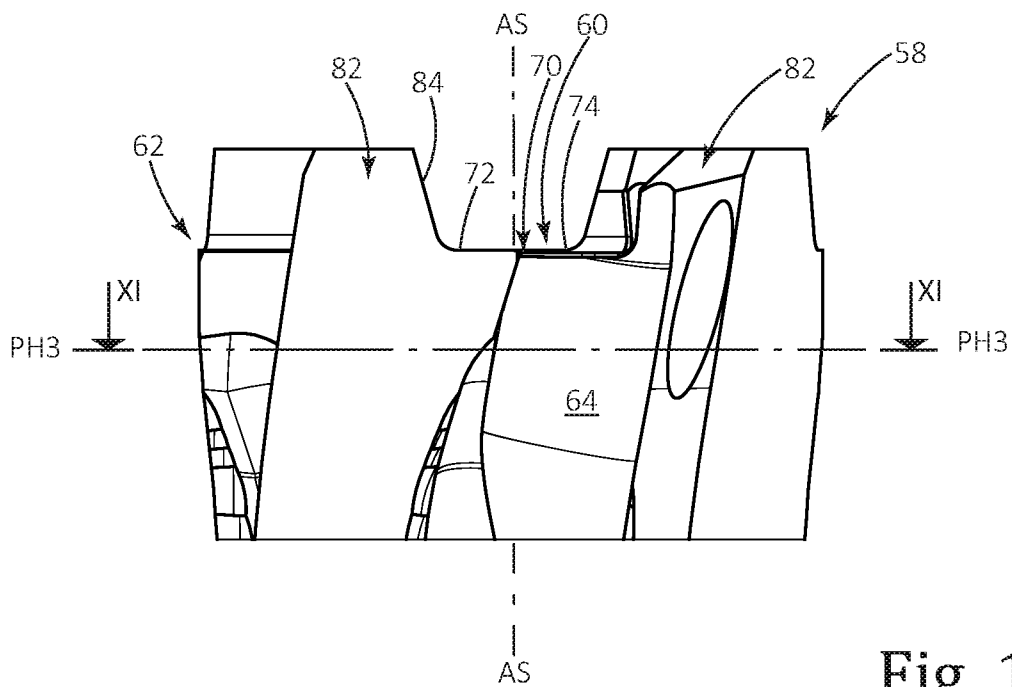


Fig. 10

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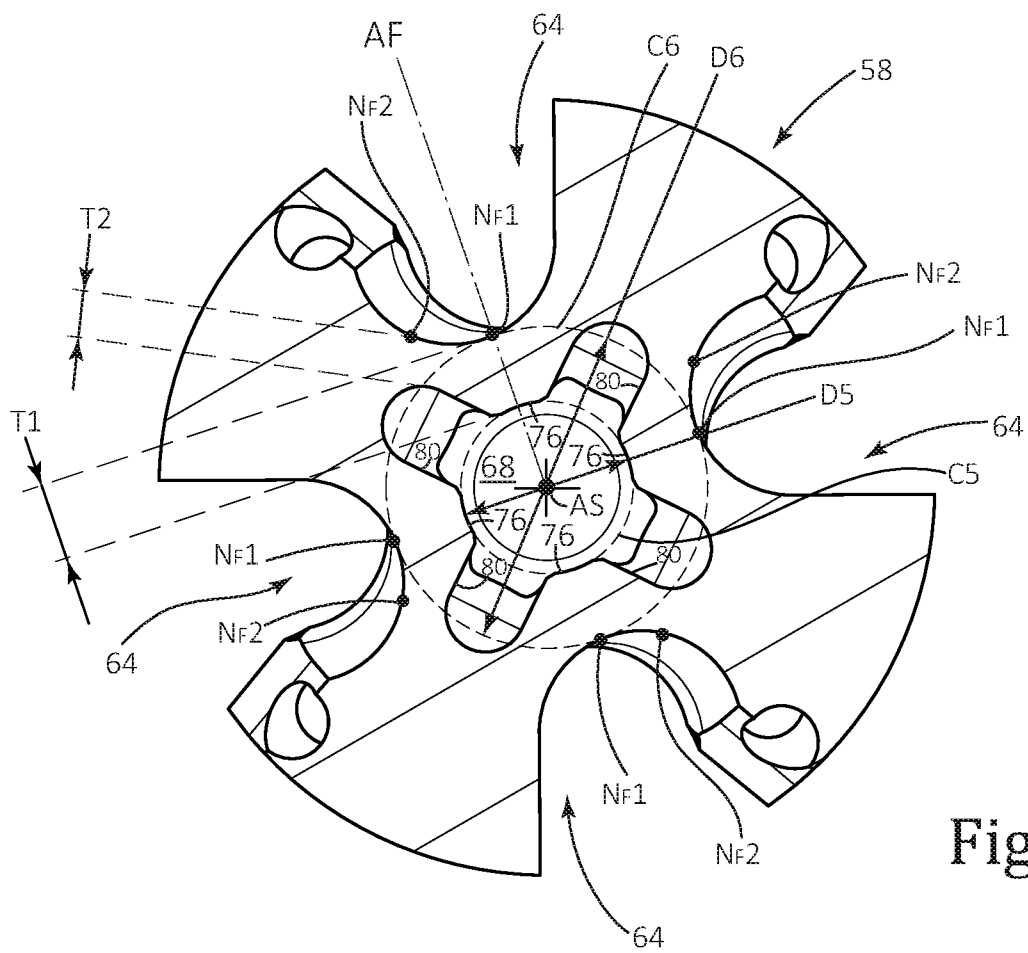


Fig. 11

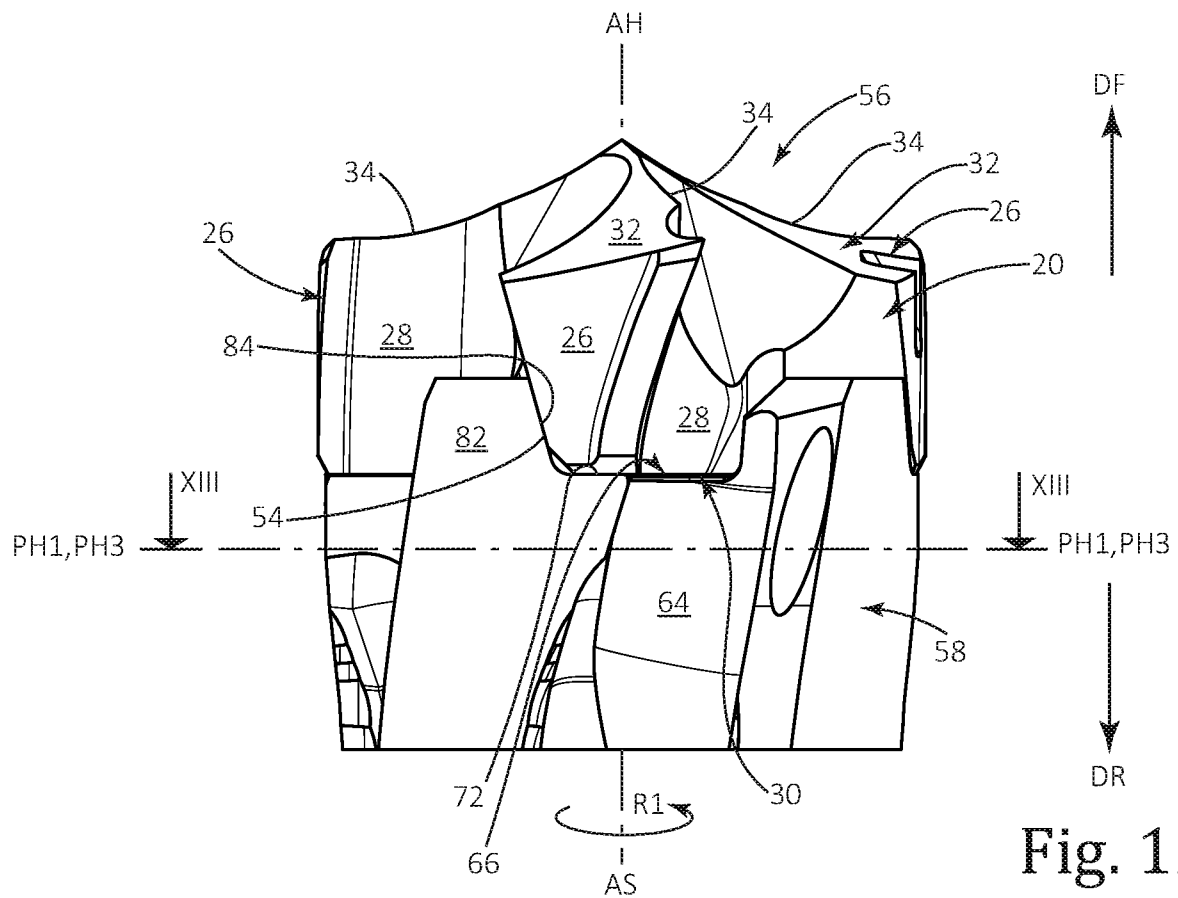


Fig. 12

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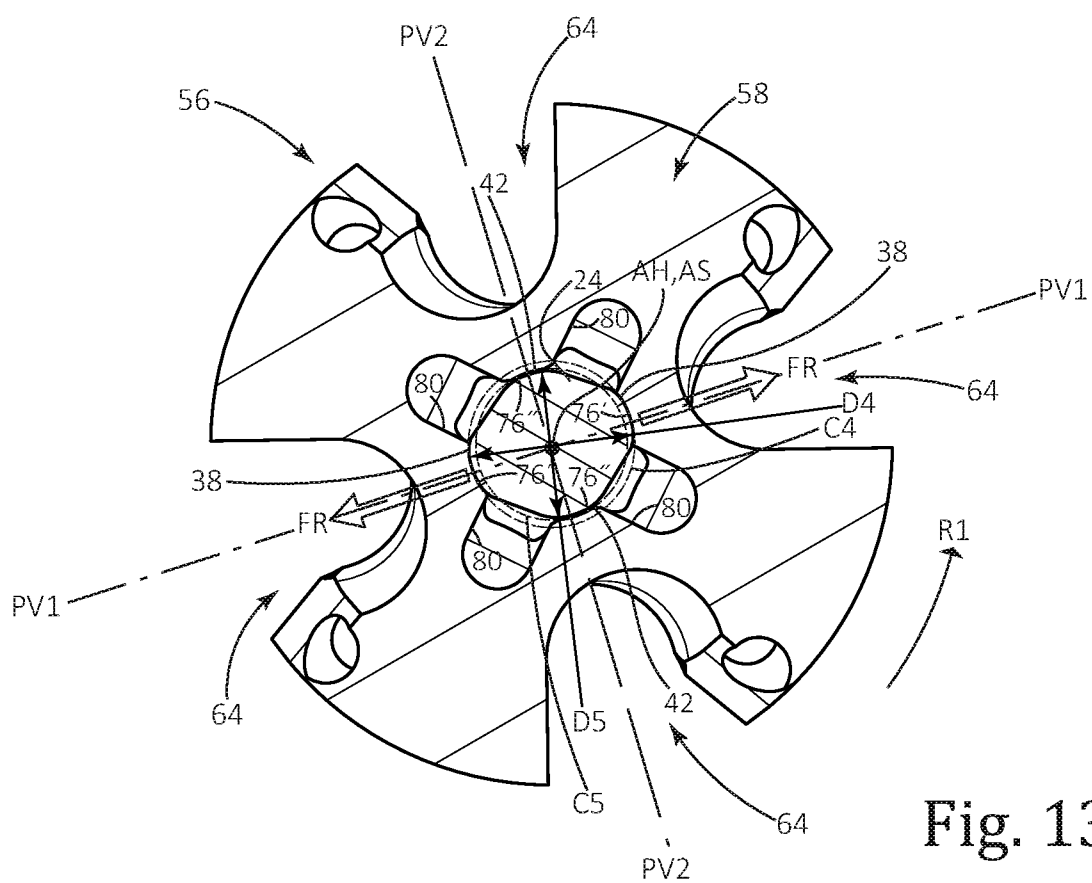


Fig. 13

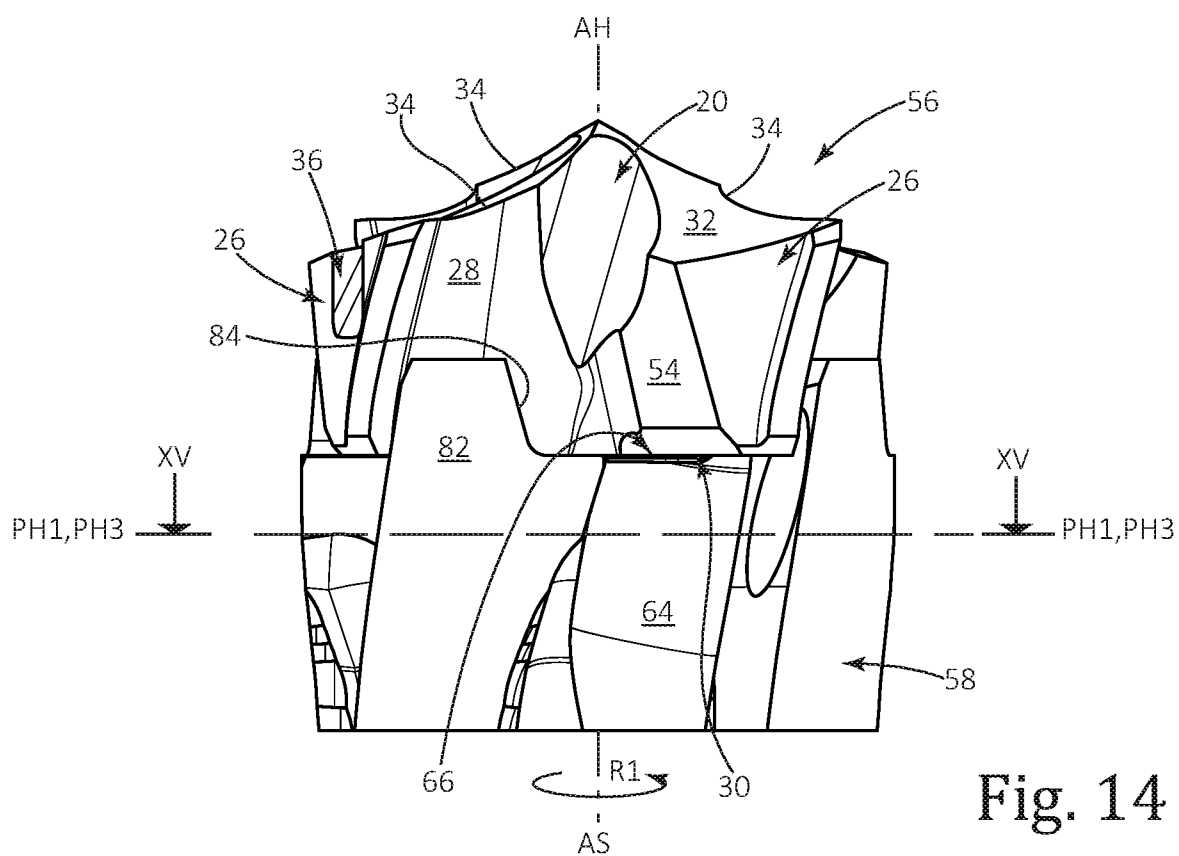


Fig. 14

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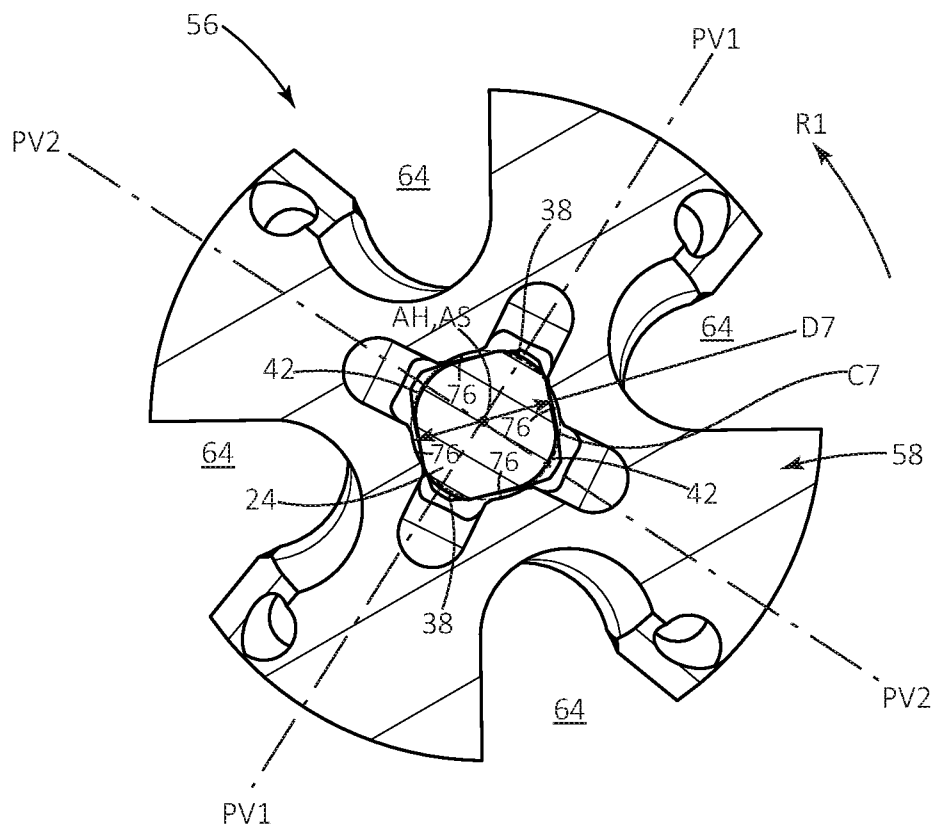


Fig. 15

INTERNATIONAL SEARCH REPORT

International application No

PCT/IL2022/051097

A. CLASSIFICATION OF SUBJECT MATTER

INV. B23B51/00 B23D1/02

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 B23G B23C B23D

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 11 110 521 B2 (ISCAR LTD [IL]) 7 September 2021 (2021-09-07) cited in the application abstract column 2, line 8 - line 52 column 9, line 3 - line 20 figures 1-22 -----	1-25
A	EP 1 476 269 A1 (KENNAMETAL INC [US]) 17 November 2004 (2004-11-17) abstract paragraphs [0020], [0022] figures 1-3, 5 -----	1-10, 12-25
A	US 8 992 142 B2 (ISCAR LTD [IL]) 31 March 2015 (2015-03-31) abstract figures 1-7 -----	1, 25
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Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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Date of the actual completion of the international search

14 February 2023

Date of mailing of the international search report

24/02/2023

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/IL2022/051097

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IL2022/051097

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