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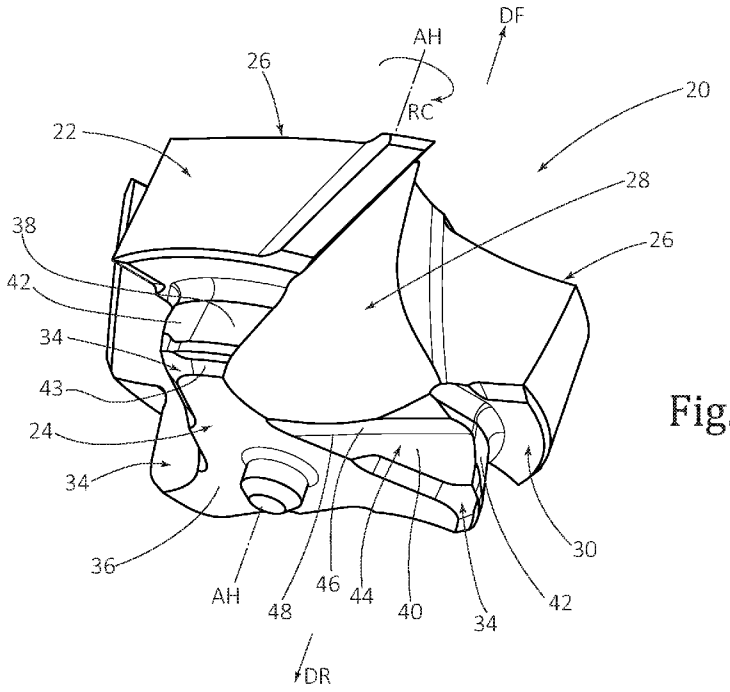


Fig. 2

(57) Abstract: A cutting head rotatable about a head axis has a cap portion and a mounting protuberance joined thereto. The cap portion has N cutting portions circumferentially alternating with N head flutes. The mounting protuberance has N circumferentially spaced apart engagement portions, each including a radially outward facing clamping surface and a torque transmission surface. In a cross- section taken in a head plane perpendicular to the head axis, a first imaginary circle having a first diameter circumscribes the N clamping surfaces, and N radially outermost torque points of the N torque transmission surfaces define a second imaginary circle having a second diameter. The second diameter is greater than ninety percent of the first diameter. A rotary cutting tool includes a tool shank extending along a shank axis and a head receiving pocket at a forward end thereof, and the cutting head is releasably secured in the head receiving pocket.

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ROTATABLE CUTTING HEAD HAVING TORQUE TRANSMISSION SURFACES ON A MOUNTING PROTUBERANCE AND ROTARY CUTTING TOOL

FIELD OF THE INVENTION

The present invention relates to a rotatable cutting head having torque transmission surfaces on a mounting protuberance and a rotary cutting tool having such cutting head, for use in metal cutting processes in general, and for drilling operations in particular.

BACKGROUND OF THE INVENTION

Within the field of cutting tools used in drilling operations, there are some examples of rotary cutting tools with cutting heads having torque transmission surfaces on a mounting protuberance.

US 6,582,164 discloses a removable tip having a front end and a rear end. The front end has two cutting portions circumferentially alternating with a two chip flutes, and the rear end is defined by a shaft, adapted to be inserted in the connection bore of a drill body, and having diametrically opposed external threads extending therefrom. Each external thread has a diminishing radius defining a drive face which cooperates with the drive face of a corresponding internal thread of the drill body, for transmitting rotational forces between the drill body and the removable tip.

US 10,071,430 discloses a cutting head formed for insertion into a support in a modular rotary tool. The cutting head has a coupling pin having torque surfaces and clamping surfaces on its outer periphery. The coupling pin is divided into a front pin part and a rear pin part. The front pin part is defined by a circumferential groove. Stop surfaces for an axial pullout safety are formed in the transition area between the two the front pin part and the rear pin part. The torque surfaces and the clamping surfaces are arranged in different pin parts. The clamping surfaces are preferably formed on the front pin part and the torque surfaces are preferably formed in the rear pin part.

It is an object of the present invention to provide an improved rotatable cutting head rotatable having torque transmission surfaces on a mounting protuberance.

It is also an object of the present invention to provide an improved rotatable cutting head, configured for a high level of torque transfer between a tool shank and the mounting protuberance.

It is a further object of the present invention to provide an improved rotary cutting tool, configured for efficient and optimized torque transfer between the tool shank and the rotatable cutting head.

SUMMARY OF THE INVENTION

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

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

a mounting protuberance joined to the cap portion, extending axially rearwardly from the cap base surface, and having:

a mounting end surface distal from the cap portion, facing in the axial rearward direction, and

N circumferentially spaced apart engagement portions,

each engagement portion including a radially outward facing clamping surface, and a torque transmission surface facing opposite the direction of cutting rotation,

wherein:

N is an integer greater than 1, and

in a cross-section taken in a first head plane perpendicular to the head axis, intersecting the N engagement portions and passing through the N clamping surfaces and the N torque transmission surfaces:

a first imaginary circle centered about the head axis and having a first diameter circumscribes the N clamping surfaces,

a second imaginary circle centered about the head axis and having a second diameter, is defined by N radially outermost torque points of the N torque transmission surfaces, and

the second diameter is greater than ninety percent and less than one hundred percent of the first diameter.

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

a tool shank extending along a shank axis and having a head receiving pocket at a forward end thereof, and

a cutting head of the sort described above, releasably secured to the head receiving pocket, in an assembled position of the tool.

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 first perspective view of a cutting head in accordance with some embodiments of the present invention;

Fig. 2 is a second perspective view of the cutting head in accordance with some embodiments of the present invention;

Fig. 3 is a front view of the cutting head shown in Figs. 1 and 2;

Fig. 4 is a rear view of the cutting head shown in Figs. 1 and 2;

Fig. 5 is a side view of the cutting head shown in Figs. 1 and 2;

Fig. 6 is a cross-sectional view of the cutting head shown in Fig. 5, taken along the line VI-VI;

Fig. 7 is a cross-sectional view of the cutting head shown in Fig. 5, taken along the line VII-VII;

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

Fig. 9 is an exploded perspective view of the rotary cutting tool shown in Fig. 8;

Fig. 10 is a side view of the rotary cutting tool shown in Fig. 8;

Fig. 11 is a cross-sectional view of the rotary cutting tool shown in Fig. 10, taken along the line XI-XI; and

Fig. 12 is a front view of a tool shank in accordance with some embodiments of the present invention.

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 direction of cutting rotation **RC**.

The head axis **AH** establishes an axial forward direction **DF** and an axial rearward direction **DR**.

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.

The cutting head **20** comprises a cap portion **22**, and a mounting protuberance **24** joined to the cap portion **22**.

As shown in Figs. 1 to 5, the cap portion **22** has N cutting portions **26** circumferentially alternating with N head flutes **28**, and a cap base surface **30** facing in the axial rearward direction **DR**.

It should be appreciated throughout the description and claims, that N is a specific integer number greater than one, and thus the plurality of head flutes **28** are equal in number to the plurality of cutting portions **26**.

As shown in Fig. 3, each cutting portion **26** may have a radially extending cutting edge **32**, and N radially outermost cutting points **NCO** of the N radially extending cutting edges **32** may define an imaginary cutting circle **CC** having a cutting diameter **DC**.

In some embodiments of the present invention, it should be appreciated that the imaginary cutting circle **CC** may have a center coincident with the head axis **AH**.

Also, in some embodiments of the present invention, the cutting head **20** may be used for drilling operations. Thus, the cutting head **20** can be a drill head with radially extending cutting edges **32** also extending in the axial rearward direction **DR**.

Further, in some embodiments of the present invention, the cutting head **20** may exhibit N-fold rotational symmetry about the head axis **AH**.

As shown in Figs. 1 to 5, the mounting protuberance **24** extends axially rearwardly from the cap base surface **30** and includes N circumferentially spaced apart engagement portions **34**.

It should be appreciated that the N engagement portions **34** are equal in number to the N cutting portions **26**.

In some embodiments of the present invention, the cap base surface **30** may be perpendicular to the head axis **AH**.

Also, in some embodiments of the present invention, the cap base surface **30** may comprise N circumferentially spaced apart co-planar cap base sub-surfaces **30a**.

The mounting protuberance **24** also includes a mounting end surface **36** distal from the cap portion **22**, facing in the axial rearward direction **DR**.

In some embodiments of the present invention, the N head flutes **28** may extend axially rearwardly from the cap portion **22** and intersect the mounting end surface **36**, and the plurality of N engagement portions **34** may circumferentially alternate with the N head flutes **28**.

Also, in some embodiments of the present invention, the mounting end surface **36** may be planar.

Further, in some embodiments of the present invention, as shown in Fig. 5, the mounting end surface **36** may be axially spaced apart from the cap base surface **30** by a first height **H1**, and the first height **H1** may be less than thirty percent of the cutting diameter **DC**, i.e. $\mathbf{H1} < 0.30*\mathbf{DC}$.

For embodiments of the present invention, in which the first height **H1** is less than thirty percent of the cutting diameter **DC**, the mounting protuberance **24** may be considered axially compact, and the cutting head **20** may be advantageously manufactured from a reduced amount of cemented carbide.

As shown in Figs. 1 to 5, each engagement portion **34** has a radially outward facing clamping surface **38**, and a torque transmission surface **40** facing opposite the direction of cutting rotation **RC**. In the mounting protuberance **24**, the clamping surfaces **38** and the torque transmission surfaces **40** overlap in the axial direction (i.e., along the head axis **AH**).

In some embodiments of the present invention, with respect to the direction of cutting rotation **RC**, each clamping surface **38** may be located rotationally ahead of its associated torque transmission surface **40**.

Also, in some embodiments of the present invention, the clamping surface **38** and the torque transmission surface **40** of each engagement portion **34** may be circumferentially spaced apart by a corner surface **42**.

Further, in some embodiments of the present invention, as shown in Fig. 5, the N clamping surfaces **38** may taper in the axial forward direction **DF**.

Yet further, in some embodiments of the present invention, each clamping surface **38** may not intersect the mounting end surface **36**.

As shown in Figs. 2, 4 and 5, each engagement portion **34** may include an end chamfer **43**, and each clamping surface **38** may be spaced apart from the mounting end surface **36** by its associated end chamfer **43**.

By configuring the N torque transmission surfaces **40** to be disposed on the mounting protuberance **24**, as opposed to the cap portion **22**, advantageously allows the cutting portions **26** to be arranged in an optimized manner, for example, with respect to cutting chip development and cutting chip flow, without the requirement to provide additional space for torque transfer between a tool shank and the cutting head's cap portion **22**.

It should be appreciated that the significance of arranging the cutting portions **26** in an optimized manner is greater for cap portions **22** having smaller cutting diameters, and for cutting heads **20** having a value of N which is greater than two, i.e. $N > 2$.

As shown in Fig. 6, in a cross-section taken in a first head plane **PH1** perpendicular to the head axis **AH**, intersecting the N engagement portions **34**, and passing through both the clamping surfaces **38** and the torque transmission surfaces **40**, a first imaginary circle **C1** having a first diameter **D1** circumscribes the N clamping surfaces **38**.

In some embodiments of the present invention, in the cross-section taken in the first head plane **PH1**, each clamping surface **38** may lie on the first imaginary circle **C1**.

Also, in some embodiments of the present invention, the first diameter **D1** may be greater than seventy percent of the cutting diameter **DC**, i.e. $D1 > 0.70*DC$.

Further, in some embodiments of the present invention, it should be appreciated that the first imaginary circle **C1** may have a center coincident with the head axis **AH**.

As shown in Fig. 6, in the cross-section taken in the first head plane **PH1**, N radially outermost torque points **NTO** of the N torque transmission surfaces **40** define a second imaginary circle **C2** having a second diameter **D2**.

It should be appreciated throughout the description and claims, that the N radially outermost torque points **NTO** may not be the absolute radially outermost torque points of the N torque transmission surfaces **40**, but the radially outermost torque points of the N torque transmission surfaces **40** in the first head plane **PH1**.

In some embodiments of the present invention, it should be appreciated that the second imaginary circle **C2** may have a center coincident with the head axis **AH**.

According to the first aspect of the present invention, the second diameter **D2** is greater than ninety percent and less than one hundred percent of the first diameter **D1**, i.e. $0.90*\mathbf{D1} < \mathbf{D2} < 1.00*\mathbf{D1}$.

In some embodiments of the present invention, the second diameter **D2** may be greater than ninety-five percent and less than one hundred percent of the first diameter **D1**, i.e. $0.95*\mathbf{D1} < \mathbf{D2} < 1.00*\mathbf{D1}$.

It should be appreciated that configuring the N torque transmission surfaces **40** such that the second diameter **D2** is greater than ninety percent of the first diameter **D1**, advantageously enables a high level of torque transfer between a tool shank and the mounting protuberance **24**.

It should be also appreciated that for embodiments of the present invention in which the first diameter **D1** is greater than seventy percent of the cutting diameter **DC**, a high level of torque transfer can be further ensured.

As shown in Fig. 6, in the cross-section taken in the first head plane **PH1**, each corner surface **42** may be convexly curved, and tangentially adjoin its associated clamping surface **38**.

Also, as shown in Fig. 6, in the cross-section taken in the first head plane **PH1**, each torque transmission surface **40** may extend linearly from its respective radially outermost torque point **NTO** and define a first imaginary straight line **L1**.

In some embodiments of the present invention, as shown in Fig. 6, each first imaginary straight line **L1** may pass through another portion of the mounting protuberance **24**.

Also, in some embodiments of the present invention, each torque transmission surface **40** may be planar.

As shown in Fig. 6, each radially outermost torque point **NTO** may be contained in a second head plane **PH2** containing the head axis **AH**.

Also, as shown in Fig. 6, in the cross-section taken in the first head plane **PH1**, each first imaginary straight line **L1** may form a first angle **α1** with its associated second head plane **PH2**.

In some embodiments of the present invention, the first angle **α1** may be less than thirty-five degrees, i.e. **α1** < 35°.

It should be appreciated that for embodiments of the present invention in which the first angle **α1** is less than thirty-five degrees, the N torque transmission surfaces **40** are advantageously oriented so that torque transfer between a tool shank and the mounting protuberance **24** can occur efficiently.

As shown in Fig. 1 to 5, N may equal three, i.e. N = 3, and as shown in Fig. 6, in the cross-section taken in the first head plane **PH1**, the plurality of N torque transmission surfaces **40** may define an imaginary torque triangle **TT**.

In some embodiments of the present invention, as shown in Fig. 6, the N radially outermost torque points **NTO** of the N torque transmission surfaces **40** may be located outside imaginary torque triangle **TT**.

Also, in some embodiments of the present invention, a third imaginary circle **C3** having a third diameter **D3** may inscribe the torque triangle **TT**, and the third diameter **D3** may be less than sixty percent of the first diameter **D1**, i.e. **D3** < 0.60***D1**.

It should be appreciated that for embodiments of the present invention in which the third diameter **D3** is less than sixty percent of the first diameter **D1**, the N torque transmission surfaces **40** are advantageously oriented so that torque transfer between a tool shank and the mounting protuberance **24** can occur efficiently.

In some embodiments of the present invention, the N torque transmission surfaces **40** may be outwardly inclined in the axial forward direction **DF**, such that as shown in Fig. 6, the portions of the N torque transmission surfaces **40** axially forward of the first head plane **PH1** are located outside of the torque triangle **TT**.

It should be appreciated that for embodiments of the present invention in which the N torque transmission surfaces **40** are outwardly inclined in the axial forward direction **DF**, the N engagement portions **34** may be highly robust.

As shown in Fig. 1 to 5, each torque surface **40** may be formed in a torque cut-out **44** of its respective engagement portion **34**.

In some embodiments of the present invention, each torque transmission surface **40** may intersect an adjacent joining surface **46** to form a straight torque border edge **48**.

As shown in Fig. 5, each torque transmission surface **40** may define a third head plane **PH3**, and each third head plane **PH3** may intersect the mounting protuberance **24** along its associated torque border edge **48**.

In some embodiments of the present invention, each joining surface **46** may intersect one of the head flutes **28**.

As shown in Fig. 7, each torque border edge **48** defines a second imaginary straight line **L2** which may not intersect or pass through any other portion of the mounting protuberance **24**.

Also, as shown in Fig. 7, apart from each second imaginary second straight line **L2** being coincident with its respective torque border edge **48**, each second imaginary straight line **L2** may not intersect or pass through any other portion of the cutting head **20**. This can be appreciated by observing in Fig. 7 that neither of the two portions of the second imaginary straight line **L2** extending from the ends of the torque border edge **48** overlap the 'cut' or 'hatched' portion of the cutting head **20**.

In some embodiments of the present invention, as shown in Fig. 5, each second imaginary straight line **L2** may intersect the first head plane **PH1**.

Also, in some embodiments of the present invention, as shown in Fig. 5, each torque border edge **48** may intersect the first head plane **PH1**.

Further, in some embodiments of the present invention, as shown in Figs. 5 and 7, each torque border edge **48** may intersect the mounting end surface **36**.

It should be appreciated that for embodiments of the present invention in which apart from being coincident with its respective torque border edge **48**, each second imaginary straight line **L2** does not intersect or pass through any other portion of the cutting head **20**, the associated torque transmission surface **40** may be formed by means of a grinding operation, whereby sufficient

clearance is provided for a large diameter grinding wheel typically used to perform such grinding operation.

It should also be appreciated that the N torque transmission surfaces **40** may be highly accurate following a grinding operation.

For such embodiments of the present invention, the mounting protuberance **24** may be configured such that the first imaginary straight line **L1** associated with each torque transmission surface **40** passes through another portion of the mounting protuberance **24**, for example, embodiments in which N = 3.

As shown in Figs. 8 to 12, a second aspect of the present invention relates to a rotary cutting tool **50** having, in combination, a tool shank **52** extending along a shank axis **AS** and having a head receiving pocket **54** at a forward end **56** thereof, and the cutting head **20** releasably secured to the head receiving pocket **54**, in an assembled position of the tool.

In some embodiments of the present invention, the tool shank **52** may preferably be manufactured from tool steel.

Also, in some embodiments of the present invention, the rotary cutting tool **50** may be used for drilling operations. As seen in these figures, the cutting tool **50** is a drill **50** comprising a drill head **20** and a drill shank **52**.

Further, in some embodiments the cutting head **20** may be releasably secured to the head receiving pocket **54** without the requirement of an additional fastening member, such as a clamping screw.

As shown in Figs. 9 and 12, the head receiving pocket **54** may include N circumferentially spaced apart fixation portions **58**, and each fixation portion **58** may have an axially forward-facing shank support surface **60**.

In some embodiments of the present invention, the N shank support surfaces **60** may be co-planar.

Also, in some embodiments of the present invention, the N shank support surfaces **60** may be perpendicular to the shank axis **AS**.

As shown in Figs. 9 and 10, the head receiving pocket **54** may have an axially forward-facing bottom surface **62**, and the bottom surface **62** may be axially spaced apart from the N shank support surfaces **60** by a second height **H2**.

In some embodiments of the present invention, the bottom surface **62** may be planar.

As shown in Figs. 8, 10 and 11, in the assembled position of the rotary cutting tool **50**:

the cap base surface **30** may face the N shank support surfaces **60**;

the head axis **AH** may be coincident with the shank axis **AS**;

each clamping surface **38** may be in contact with a radially inward facing abutment surface **64** of one of the fixation portions **58**; and

each torque transmission surface **40** may be in contact with a drive surface **66** of one of the fixation portions **58**, with each drive surface **66** facing in the direction of cutting rotation **RC**.

As seen in Figs. 10 and 12, each drive surface **66** extends in a generally radially inward direction from its associated abutment surface **64**.

In some embodiments of the present invention, the cap base surface **30** may be in contact with the N shank support surfaces **60**.

As shown in Fig. 10, the second height **H2** may be greater than the first height **H1**.

For embodiment of the present invention in which the second height **H2** is greater than the first height **H1**, the cutting head's mounting end surface **36** may be axially spaced apart from the head receiving pocket's bottom surface **62**.

It should be appreciated that in the assembled position of the rotary cutting tool **50**, apart from the N clamping surfaces **38** being in contact with the N abutment surfaces **64**, and the N torque transmission surfaces **40** being in contact with the N drive surfaces **66**, no other surfaces of the mounting protuberance **24** may be in contact with the tool shank **52**.

As shown in Fig. 11, in a cross-section taken in a first tool plane **PT1** coincident with the first head plane **PH1**, the radially outermost point of contact between each torque transmission surface **40** and its interfacing drive surface **66** may occur at the torque transmission surface's radially outermost torque point **NTO**.

For such embodiments of the present invention, it should be appreciated that torque transfer between the N drive surfaces **66** and the N torque transmission surfaces **40** is optimized, as the most effective torque transfer occurs at the radially outermost points of contact.

In some embodiments of the present invention, with respect to the direction of cutting rotation **RC**, each abutment surface **64** may be located rotationally ahead of its associated drive surface **66**.

Also, in some embodiments of the present invention, the N abutment surfaces **64** may extend radially inwardly in the axial forward direction **DF**.

Further, in some embodiments of the present invention, the N abutment surfaces **64** and the N clamping surfaces **38** may be correspondingly inclined in the axial forward direction **DF**.

For embodiments of the present invention in which the N abutment surfaces **64** and the N clamping surfaces **38** are correspondingly inclined in the axial forward direction **DF**, clamping forces between the N abutment surfaces **64** and the N clamping surfaces **38** may be directed axially rearwardly as well as radially inwardly.

The present invention also relates to a method of assembling the rotary cutting tool **50** comprising the steps of:

a) orienting the cap base surface **30** to face the N shank support surfaces **60**;

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

c) rotationally aligning the N head flutes **28** with the N fixation portions **58**;

d) inserting the mounting protuberance **24** into the head receiving pocket **54**; and

e) rotating the cutting head **20** about the head axis **AH** opposite the direction of cutting rotation **RC** until:

the N clamping surfaces **38** are retained against the N abutment surfaces **64**, and

the N torque transmission surfaces **40** make contact with the N drive surfaces **66**.

In some embodiments of the present invention, in step d) of the tool assembly, the mounting protuberance **24** may be inserted into the head receiving pocket **54** until the cap base surface **30** makes contact with the N shank support surfaces **60**.

In step e) of the tool assembly, embodiments of the present invention having convexly curved corner surfaces **42** tangentially adjoining the N clamping surfaces **38** may advantageously enable smooth engagement of the N engagement portions **34** with the N fixation portions **58**.

It should be appreciated that in step e) of the tool assembly, it may be necessary for the second diameter **D2** to be less than one hundred percent of the first diameter **D1** for the N clamping surfaces **38** to be successfully retained against the N abutment surfaces **64**.

As shown in Figs. 8 to 12, the tool shank **50** may have a generally cylindrical shank peripheral surface **68**.

In some embodiments of the present invention, as shown in Figs. 11 and 12, the shank peripheral surface **68** may have a shank diameter **DS**, and the shank diameter **DS** may be less than the cutting diameter **DC**.

Also, in some embodiments of the present invention, the second height **H2** may be less than thirty percent of the shank diameter **DS**, i.e. **H2** < 0.30***DS**.

As shown in Figs. 8 to 12, N shank flutes **70** may be formed in the shank peripheral surface **68** and extend along the shank axis **AS**.

In some embodiments of the present invention, the N shank flutes **70** may extend axially rearwardly from the shank's forward end **56**, and the N fixation portions **58** may circumferentially alternate with the N shank flutes **70**.

Also, in some embodiments of the present invention, the N shank flutes **70** may helically extend along the shank axis **AS**.

Further, in some embodiments of the present invention, the N shank flutes **70** may intersect the head receiving pocket's bottom surface **62**.

It should be appreciated that in the assembled position of the rotary cutting tool **50**, the N shank flutes **70** may at least partially correspond with the N head flutes **28**.

As shown in Fig. 11, in the cross-section taken in the first tool plane **PT1**, each fixation portion **58** subtends a first angular extent **E1** about the shank axis **AS** between its two circumferentially adjacent shank flutes **70**.

In some embodiments of the present invention, the first angular extent **E1** may be less than eighty degrees, i.e. **E1** < 80°.

Also, in some embodiments of the present invention, the first angular extent **E1** may be less than seventy degrees, i.e. **E1** < 70°.

Further, in some embodiments of the present invention, it should be appreciated that the first angular extent **E1** is measured around the circumference of the shank peripheral surface **68**.

For embodiments of the present invention in which the first angular extent **E1** is less than eighty degrees, it should be appreciated that the N shank flutes **70** may have an increased volume, thus advantageously providing increased space for chip evacuation.

As shown in Figs. 9, 11 and 12, each abutment surface **64** may be circumferentially spaced apart from its associated drive surface **66** by a fixation recess **72** having a recess surface **74**.

As shown in Fig. 11, in the cross-section taken in the first tool plane **PT1**, each recess surface **74** may be located outside the first imaginary circle **C1**.

It should be appreciated that in the assembled position of the rotary cutting tool **50**, each recess surface **74** may be radially spaced apart from one of the cutting head's corner surfaces **42**.

Also, as shown in Fig. 11, in the cross-section taken in the first tool plane **PT1**, each recess surface **74** has a radially outermost recess point **NRO**.

In some embodiments of the present invention, each radially outermost recess point **NRO** may be located at least two times further away from the first imaginary circle **C1** than each radially outermost torque point **NTO**.

As shown in Fig. 11, each radially outermost recess point **NRO** is contained in a first shank plane **PS1** containing the shank axis **AS**, and each fixation portion **58** includes first and second fixation sub-portions **58a**, **58b** located on opposite sides of its associated first shank plane **PS1**.

It should be appreciated that in the assembled position of the rotary cutting tool **50**, each first shank plane **PS1** may intersect one of the cutting head's corner surfaces **42**.

In some embodiments of the present invention, each abutment surface **64** may be disposed on one of the first fixation sub-portions **58a**, and each drive surface **66** may be disposed on one of the second fixation sub-portions **58b**.

As shown in Fig. 11, in the cross-section taken in the first tool plane **PT1**, for embodiments of the present invention in which the shank peripheral surface **68** is generally cylindrical, a first wall thickness **T1** of each fixation portion **58** at its respective fixation recess **72** may be less than a second wall thickness **T2** of the fixation portion **58** at its circumferentially adjacent abutment surface **64**.

For such embodiments of the present invention, it should be appreciated that each first fixation sub-portion **58a** and its respective abutment surface **64** may be resiliently displaceable independently of the second fixation sub-portion **58b**.

Also, for such embodiments of the present invention, it should be appreciated the second fixation sub-portion **58b** may retain a high level of rigidity, such that torque transfer between each drive surface **66** and its interfacing torque transmission surface **40** can occur with a high level of efficiency and stability.

For embodiments of the present invention in which the second height **H2** is less than thirty percent of the shank diameter **DS**, the provision of a fixation recess **72** at each fixation portion **58** is very effective in providing the associated first fixation sub-portion **58a** with an appropriately high level of resilience during the abovementioned step e) of the tool assembly, whilst directing an appropriately high level of clamping force from its respective abutment surface **64** to the interfacing clamping surface **38**.

As shown in Figs. 8 to 12, each fixation portion **58** may include a sloping transition surface **76**, and with respect to the direction of cutting rotation **RC**, each transition surface **76** may be located rotationally behind its associated drive surface **66**.

In some embodiments of the present invention, each transition surface **76** may slope opposite the direction of cutting rotation **RC** in the axial rearward direction **DR**.

Also, in some embodiments of the present invention, as shown in Fig. 10, each transition surface **76** may intersect its adjacent trailing shank flute **70** axially rearward of the first head plane **PH1**.

Further, in some embodiments of the present invention, as shown in Fig. 12, each transition surface **76** may intersect its associated shank support surface **60** radially outward of its associated drive surface **66**.

As shown in Figs. 8 to 12, each transition surface **76** may be circumferentially spaced apart from its associated drive surface **66** by an inclined clearance surface **78**.

It should be appreciated that for some embodiments of the present invention, the N clearance surfaces **78** may be configured to provide sufficient space for step e) of the tool assembly to be carried out, without inadvertent contact between the N engagement portions **34** and the N fixation portions **58**, particularly in the region of the cutting head's N joining surfaces **46**.

As shown in Figs. 8 to 12, the tool shank **52** may include N axially extending coolant passages **80**, and each coolant passage **80** may open out to one of the transition surfaces **76**.

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. A cutting head (20) rotatable about a head axis (AH) in a direction of cutting rotation (RC), the head axis (AH) establishing an axial forward direction (DF) and an axial rearward direction (DR), comprising:

a cap portion (22) having N cutting portions (26) circumferentially alternating with N head flutes (28), and a cap base surface (30) facing in the axial rearward direction (DR); and

a mounting protuberance (24) joined to the cap portion (22), extending axially rearwardly from the cap base surface (30), and having:

a mounting end surface (36) distal from the cap portion (22), facing in the axial rearward direction (DR), and

N circumferentially spaced apart engagement portions (34), each engagement portion (34) including a radially outward facing clamping surface (38), and a torque transmission surface (40) facing opposite the direction of cutting rotation (RC),

wherein:

N is an integer greater than 1, and

in a cross-section taken in a first head plane (PH1) perpendicular to the head axis (AH), intersecting the N engagement portions (34) and passing through the N clamping surfaces (38) and the N torque transmission surfaces (40):

a first imaginary circle (C1) centered about the head axis (AH) and having a first diameter (D1) circumscribes the N clamping surfaces (38),

a second imaginary circle (C2) centered about the head axis (AH) and having a second diameter (D2), is defined by N radially outermost torque points (NTO) of the N torque transmission surfaces (40), and

the second diameter (D2) is greater than ninety percent and less than one hundred percent of the first diameter (D1).

2. The cutting head (20) according to claim 1, wherein in the cross-section taken in the first head plane (PH1), each torque transmission surface (40) extends linearly from its respective radially outermost torque point (NTO) and defines a first imaginary straight line (L1).

3. The cutting head (20) according to claim 2, wherein each first imaginary straight line (L1) passes through another portion of the mounting protuberance (24).

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

N equals 3, and

in the cross-section taken in the first head plane (PH1), the N torque transmission surfaces (40) define an imaginary torque triangle (TT).

5. The cutting head (20) according to claim 4, wherein:

the N torque transmission surfaces (40) are outwardly inclined in the axial forward direction (DF), such that in the cross-section taken in the first head plane (PH1), the portions of the N torque transmission surfaces (40) axially forward of the first head plane (PH1) are located outside the torque triangle (TT).

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

the N head flutes (28) extend axially rearwardly from the cap portion (22) and intersect the mounting end surface (36), and

the N engagement portions (34) circumferentially alternate with the N head flutes (28).

7. The cutting head (20) according to any one of the preceding claims, wherein in the cross-section taken in the first head plane (PH1), each clamping surface (38) lies on the first imaginary circle (C1).

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

each cutting portion (26) has a radially extending cutting edge (32),

N radially outermost cutting points (NCO) of the N radially extending cutting edges (32) define an imaginary cutting circle (CC) centered about the head axis (AH) and having a cutting diameter (DC), and

the first diameter (D1) is greater than seventy percent of the cutting diameter (DC).

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

the mounting end surface (36) is axially spaced apart from the cap base surface (30) by a first height (H1), and

the first height (H1) is less than thirty percent of the cutting diameter (DC).

10. The cutting head (20) according to any one of the preceding claims, wherein the N clamping surfaces (38) taper in the axial forward direction (DF).

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

each torque transmission surface (40) is formed in a torque cut-out (44) of its respective engagement portion (34),

each torque transmission surface (40) intersects an adjacent joining surface (46) to form a straight torque border edge (48), and

each torque border edge (48) defines a second imaginary straight line (L2) which does not intersect or pass through any other portion of the mounting protuberance (24).

12. The cutting head (20) according to claim 11, wherein apart from each second imaginary second straight line (L2) being coincident with its respective torque border edge (48), each second imaginary straight line (L2) does not intersect or pass through any other portion of the cutting head (20).

13. The cutting head (20) according to claim 11 or 12, wherein each torque border edge (48) intersects the first head plane (PH1).

14. The cutting head (20) according to any one of claims 11 to 13, wherein:

each torque transmission surface (40) defines a third head plane (PH3), and

each third head plane (PH3) intersects the mounting protuberance (24) along its associated torque border edge (48).

15. A rotary cutting tool (50) comprising, in combination:

a tool shank (52) extending along a shank axis (AS) and having a head receiving pocket (54) at a forward end (56) thereof, and

a cutting head (20) in accordance with any one of the preceding claims, releasably secured to the head receiving pocket (54), in an assembled position of the tool.

16. The rotary cutting tool (50) according to claim 15, wherein:

the head receiving pocket (54) comprises N circumferentially spaced apart fixation portions (58), each fixation portion (58) having an axially forward-facing shank support surface (60),

and wherein in the assembled position of the tool:

the cap base surface (30) faces the N shank support surfaces (60);

the head axis (AH) is coincident with the shank axis (AS);

each clamping surface (38) is in contact with a radially inward facing abutment surface (64) of one of the fixation portions (58); and

each torque transmission surface (40) is in contact with a drive surface (66) of one of the fixation portions (58), each drive surface (66) facing in the direction of cutting rotation (RC).

17. The rotary cutting tool (50) according to claim 16, wherein:

the N clamping surfaces (38) and the N abutment surfaces (64) are inclined in the axial forward direction (DF).

18. The rotary cutting tool (50) according to claim 16 or 17, wherein in a cross-section taken in a first tool plane (PT1) coincident with the first head plane (PH1), the radially outermost point of contact between each torque transmission surface (40) and its interfacing drive surface (66) occurs at the torque transmission surface's radially outermost torque point (NTO).

19. The rotary cutting tool (50) according to any one of claims 16 to 18, wherein

the tool shank (52) has a generally cylindrical shank peripheral surface (68), and

N shank flutes (70) are formed in the shank peripheral surface (68) and extend along the shank axis (AS).

20. The rotary cutting tool (50) according to claim 19, wherein:

the N shank flutes (70) extend axially rearwardly from the shank's forward end (56), and

the N fixation portions (58) circumferentially alternate with the N shank flutes (70).

21. The rotary cutting tool (50) according to claim 20, wherein, in a cross-section taken in a first tool plane (PT1) coincident with the first head plane (PH1):

each fixation portion (58) subtends a first angular extent (E1) about the shank axis (AS) between its two circumferentially adjacent shank flutes (70), and

the first angular extent (E1) is less than eighty degrees.

22. The rotary cutting tool (50) according to any one of claims 16 to 21, wherein:

each abutment surface (64) is circumferentially spaced apart from its associated drive surface (66) by a fixation recess (72) having a recess surface (74), and

in a cross-section taken in a first tool plane (PT1) coincident with the first head plane (PH1), each recess surface (74) is located outside the first imaginary circle (C1).

23. The rotary cutting tool (50) according to claim 22, wherein, in the cross-section taken in the first tool plane (PT1):

each recess surface (74) has a radially outermost recess point (NRO), and

each radially outermost recess point (NRO) is located at least two times further away from the first imaginary circle (C1) than each radially outermost torque point (NTO).

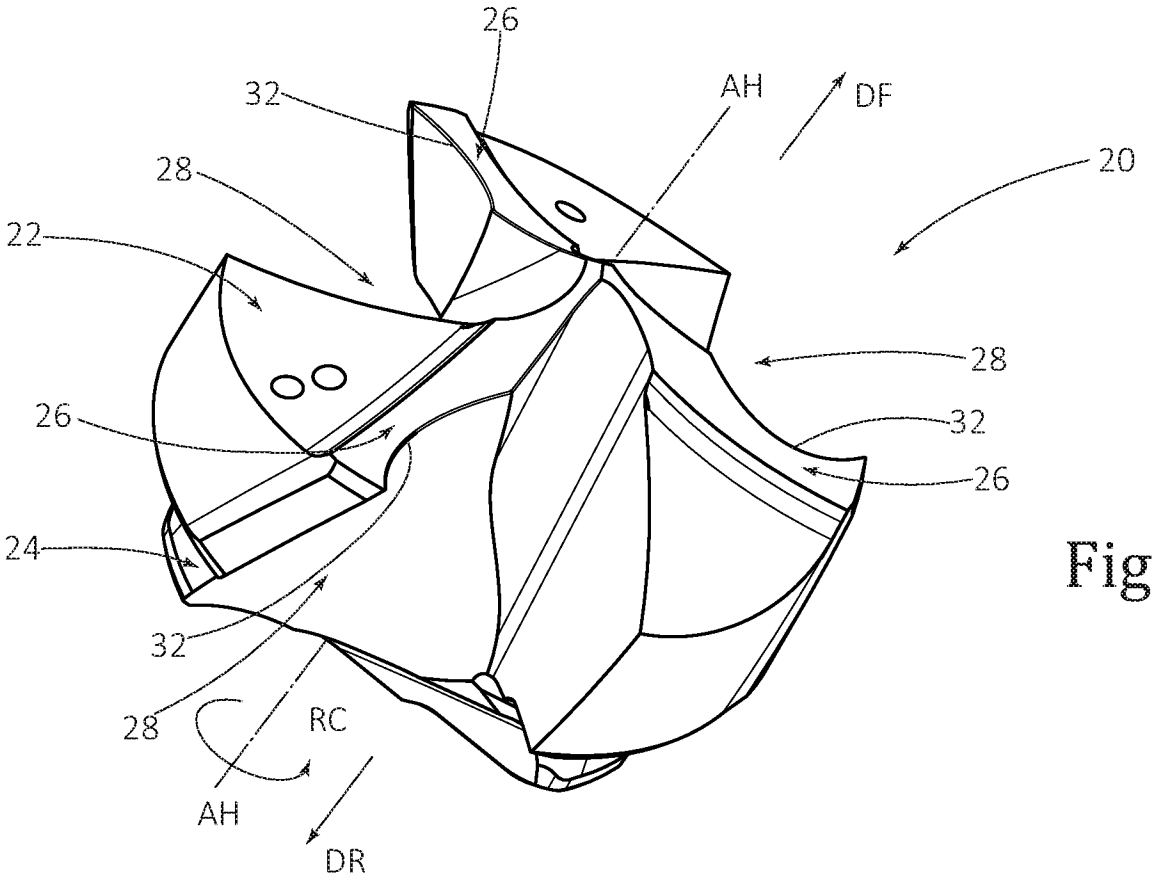

26
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AH
DF
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RC
AH
DR

Fig. 1

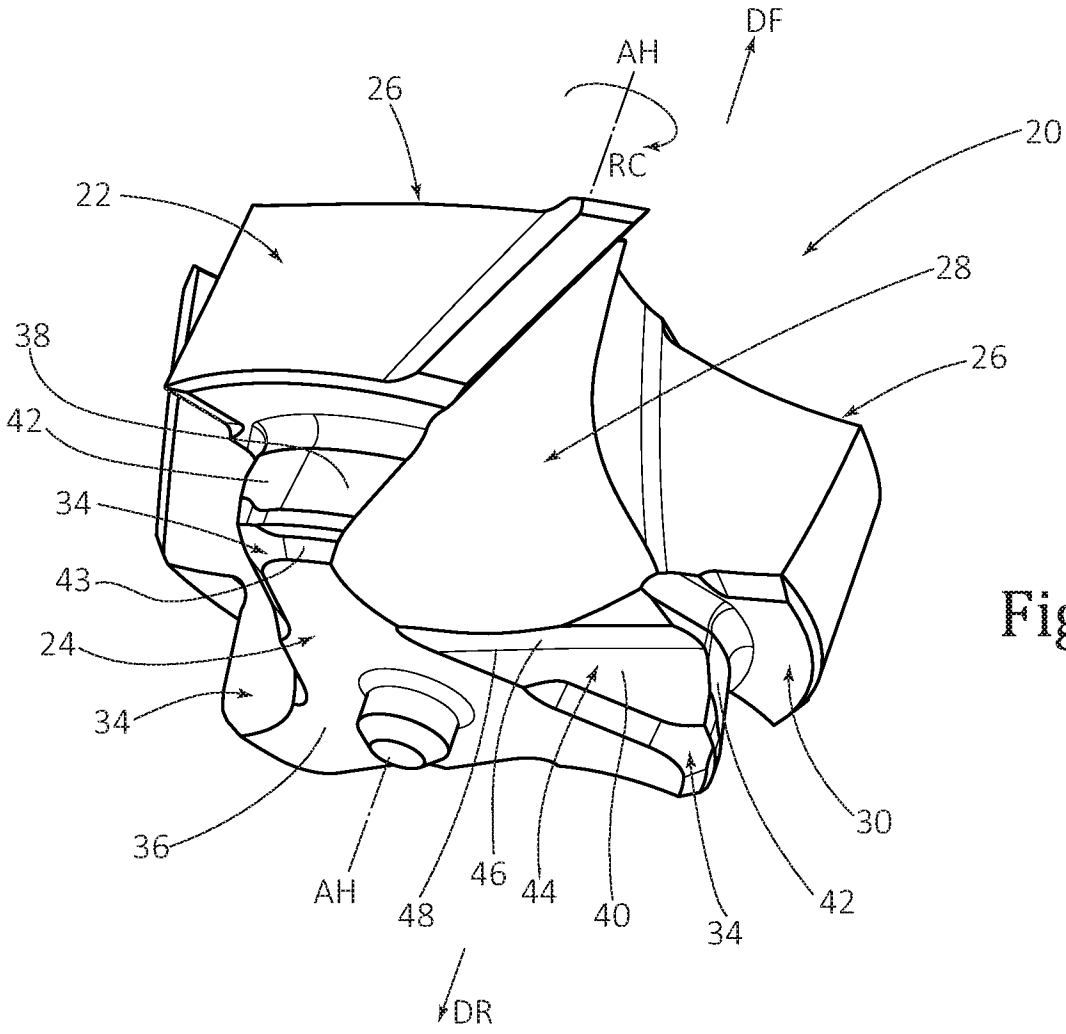

DF
AH
26
RC
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22
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38
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42
34
43
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36
AH
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44
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42
30
DR

Fig. 2

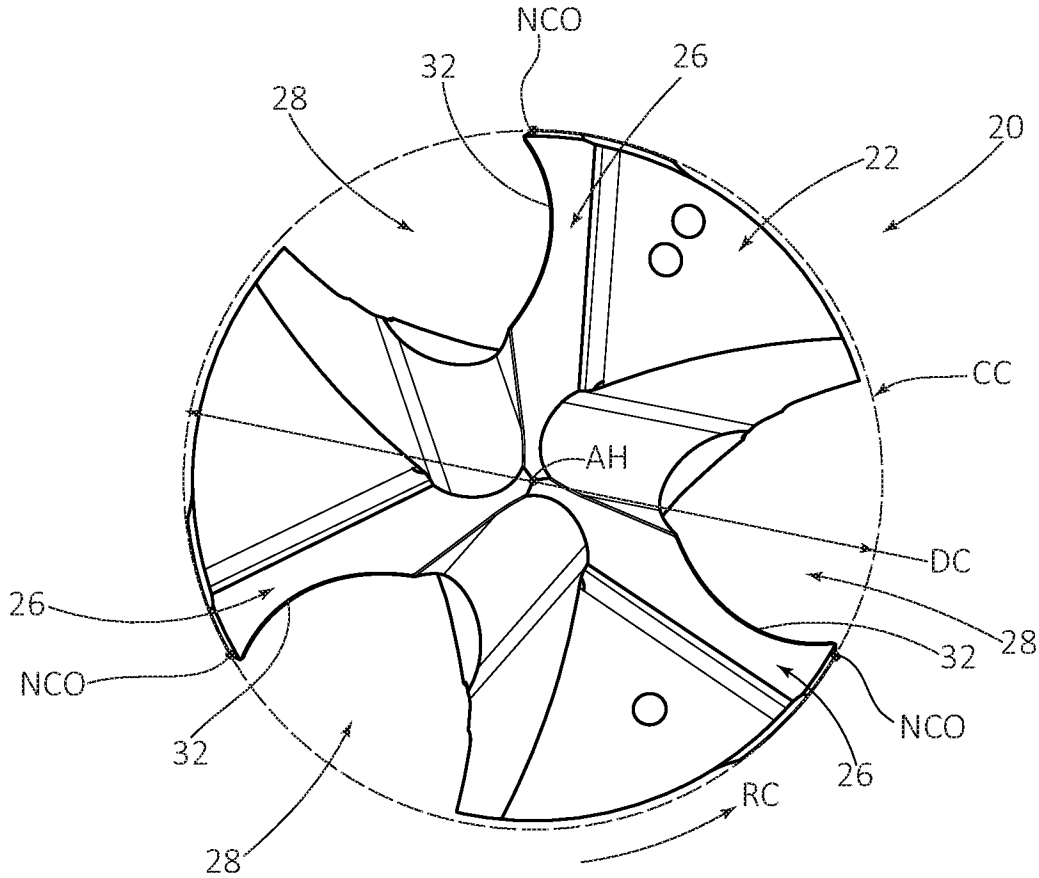

NCO
32
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20
22
CC
AH
DC
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28
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NCO
NCO
32
26
28
RC

Fig. 3

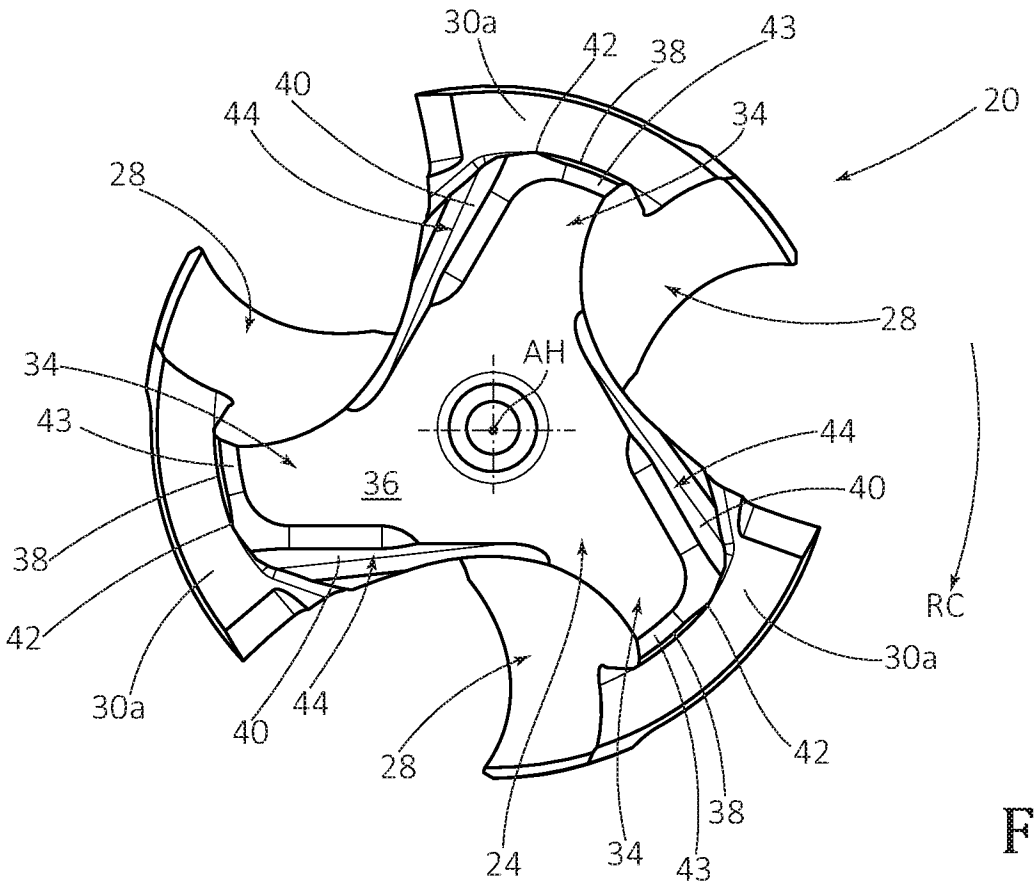

30a
42
38
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40
44
34
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AH
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Fig. 4

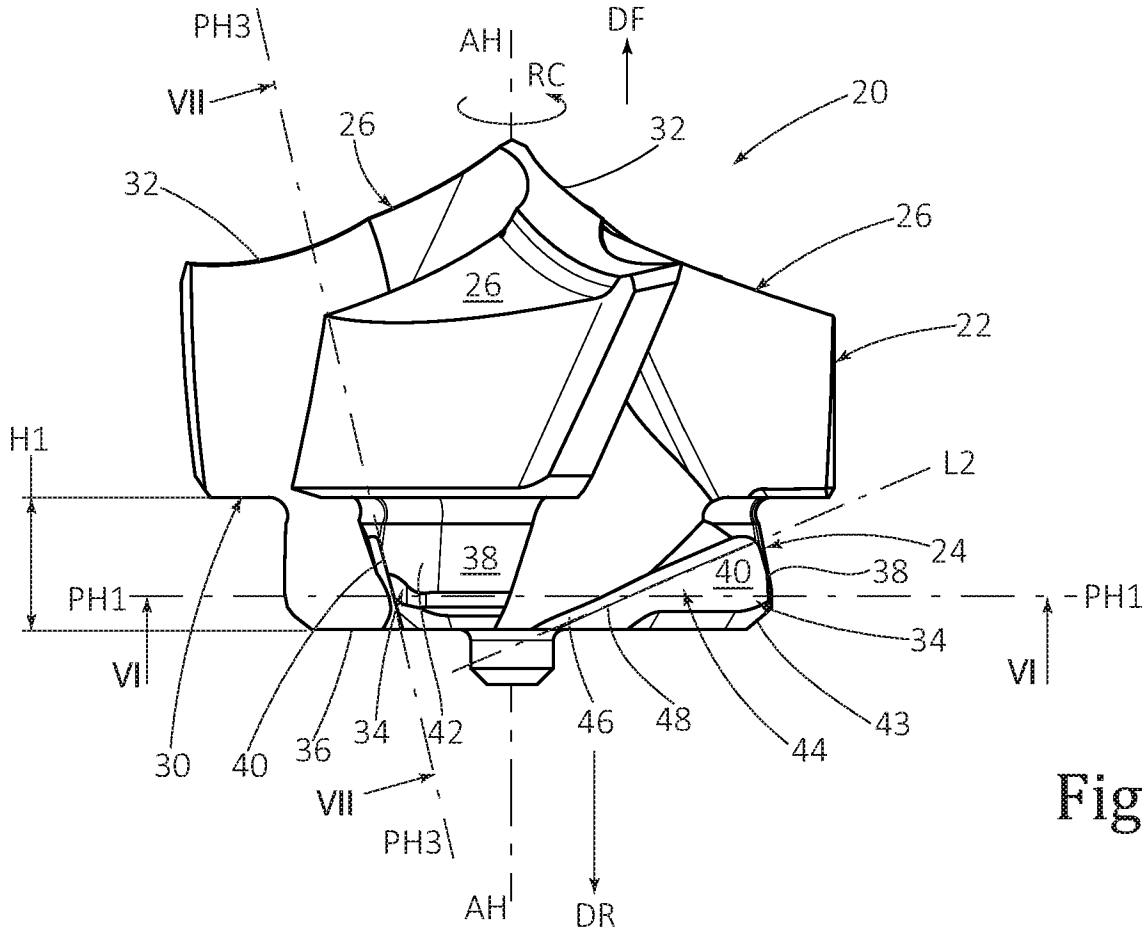

PH3
VII
AH
RC
DF
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26
32
32
26
26
22
H1
L2
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38
40
38
PH1
PH1
VI
VI
34
43
44
30
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36
34
42
46
48
VII
PH3
AH
DR

Fig. 5

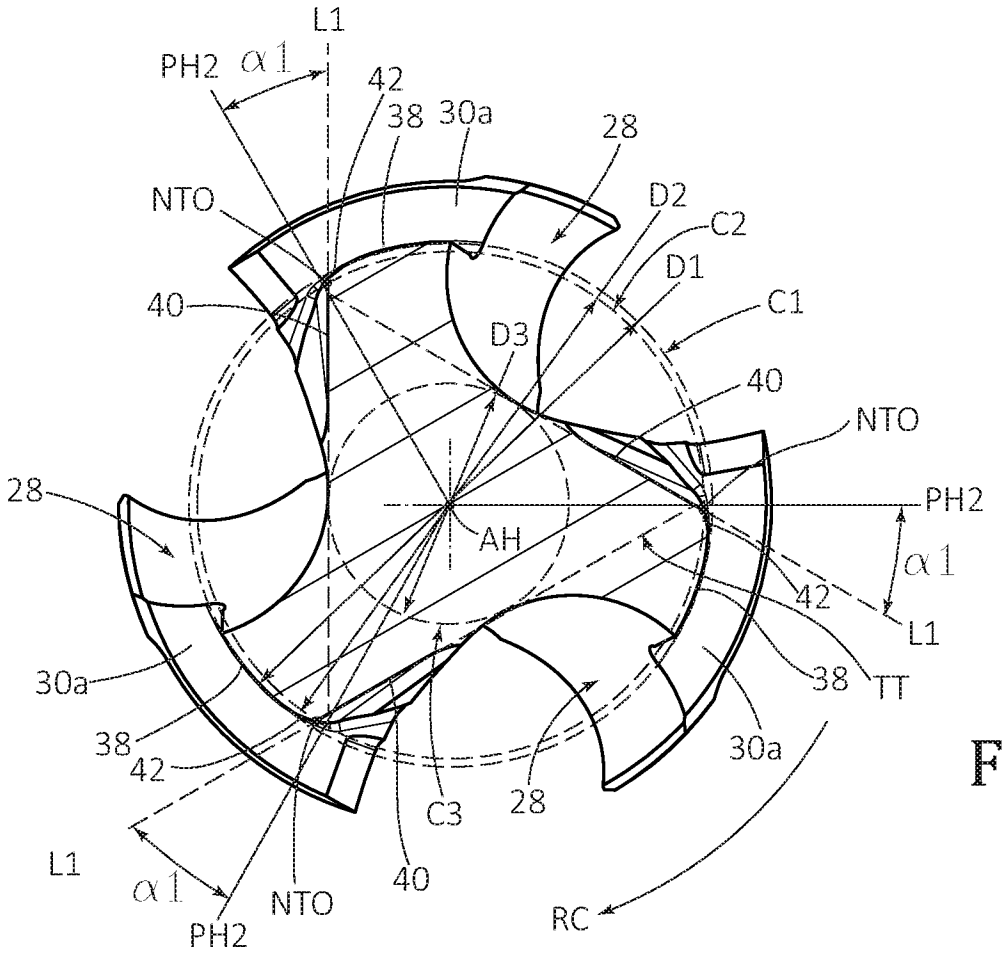

L1
PH2
α1
42
38
30a
28
NTO
D2
C2
D1
C1
40
D3
40
NTO
28
PH2
AH
α1
42
L1
30a
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TT
38
42
30a
C3
28
L1
α1
NTO
40
RC
PH2

Fig. 6

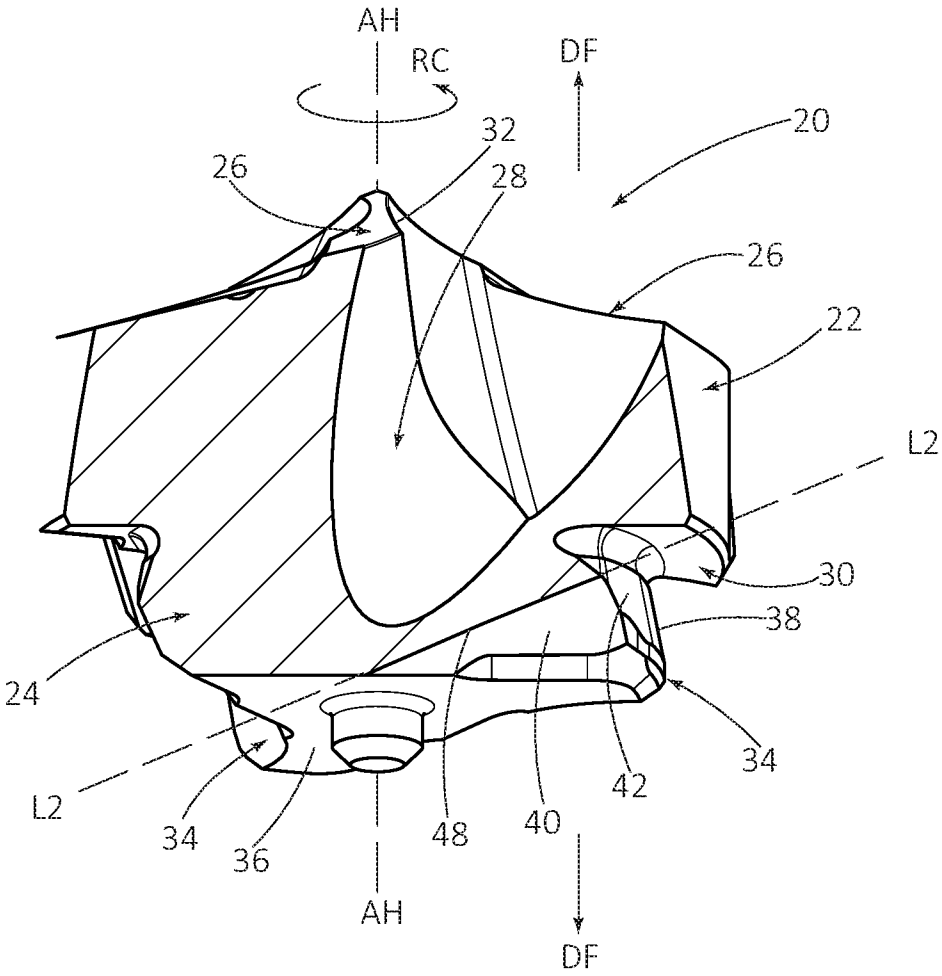

AH
RC
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L2
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L2
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48
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AH
DF

Fig. 7

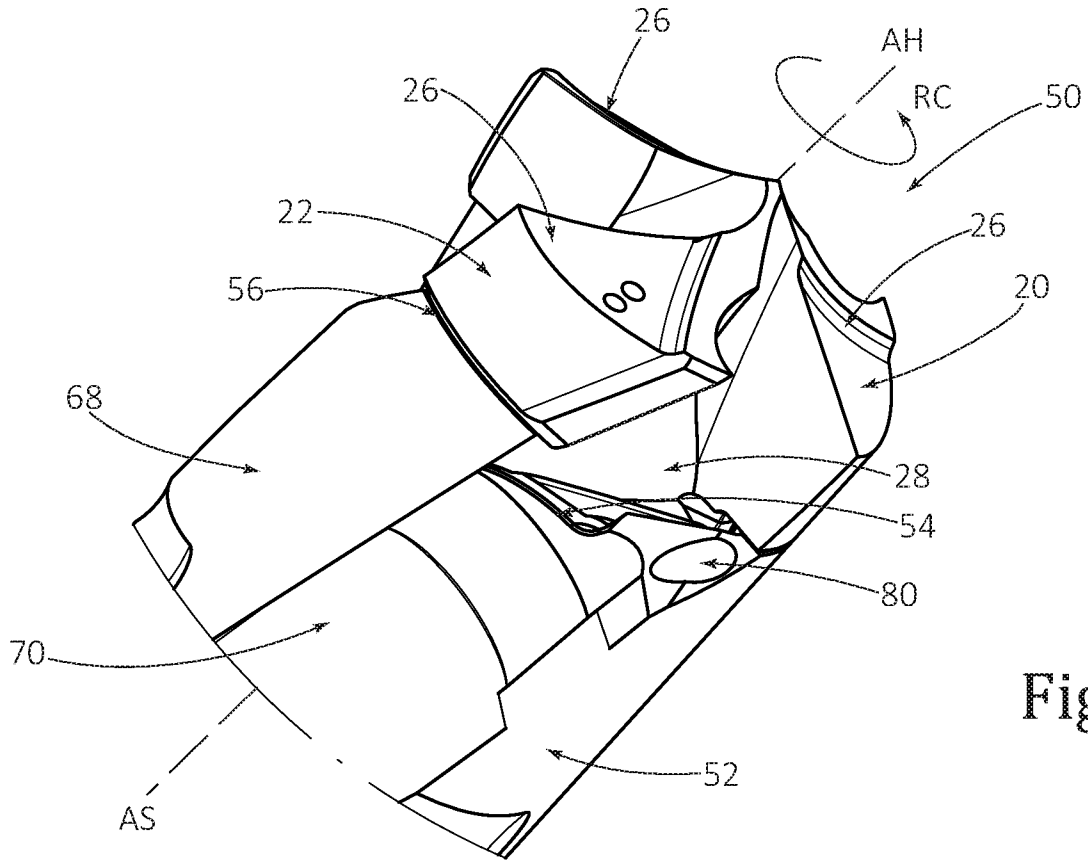

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AH
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RC
50
22
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56
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68
28
54
80
70
52
AS

Fig. 8

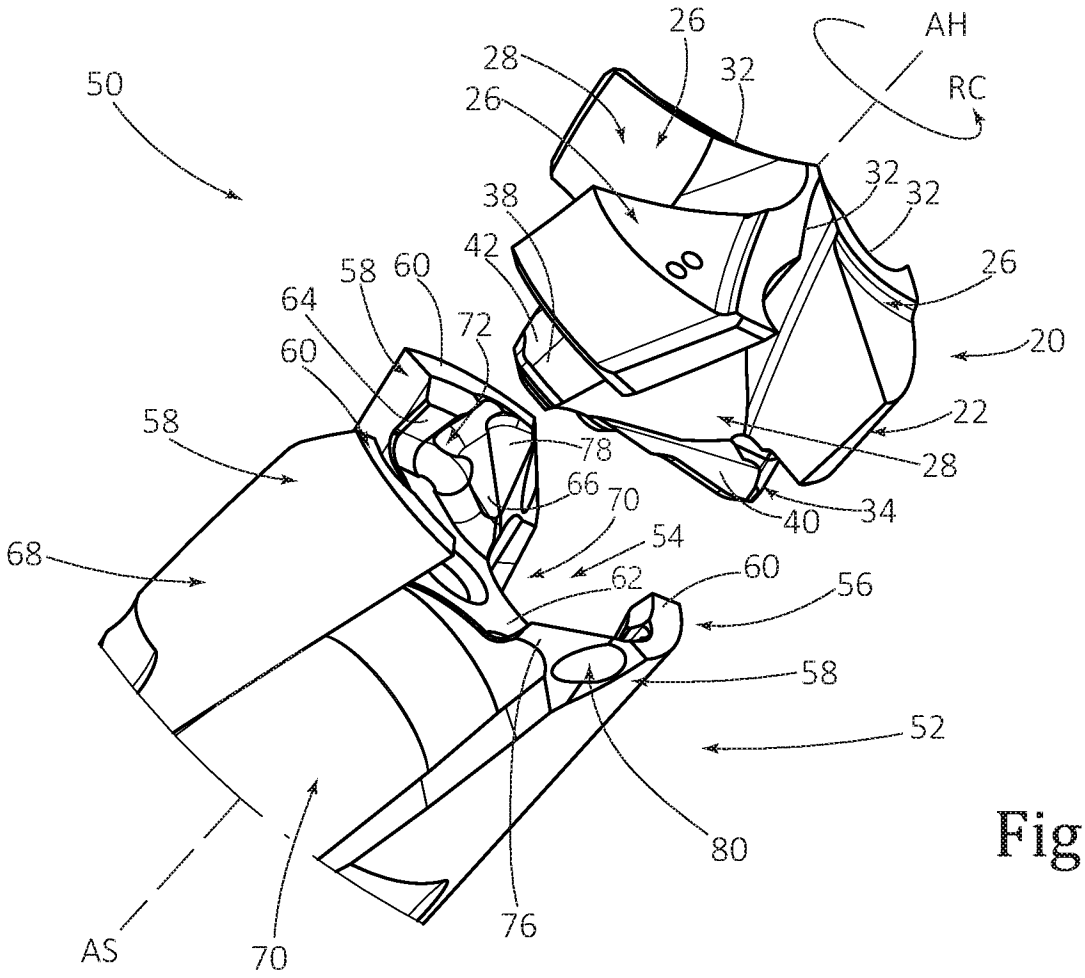

50
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AH
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68
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80
76
AS
70

Fig. 9

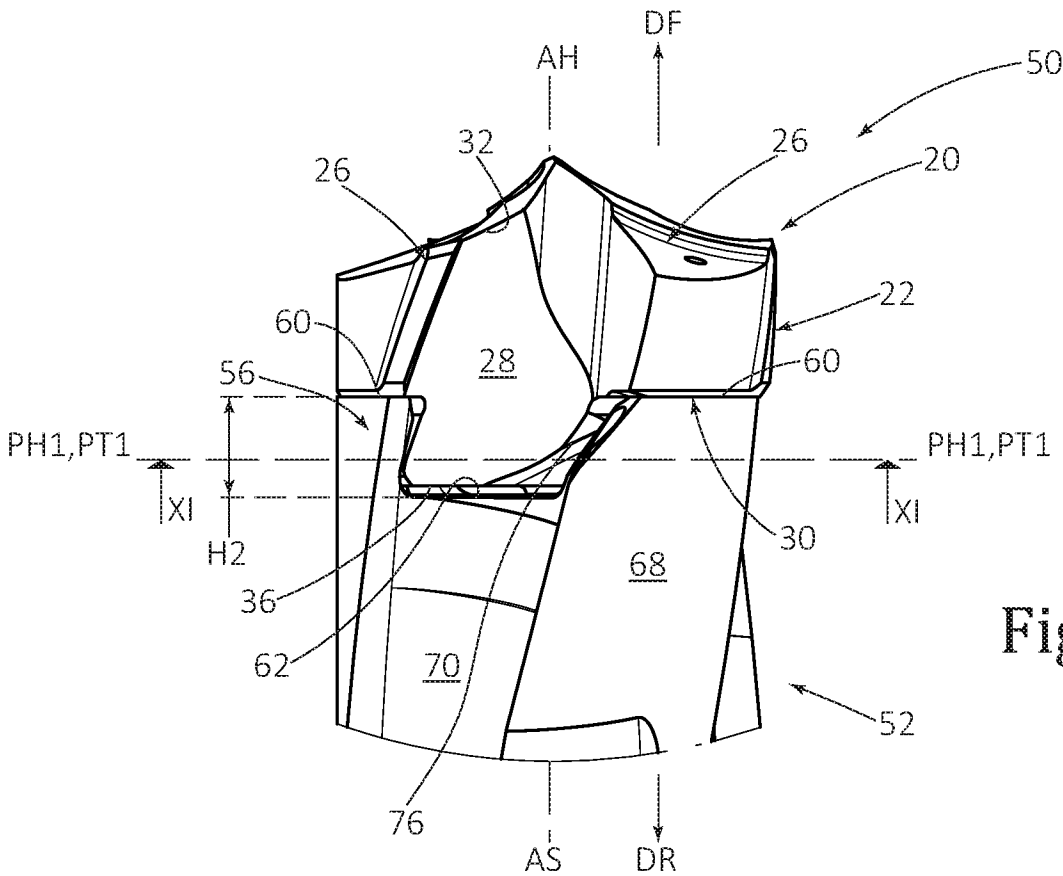

DF
AH
50
32
26
26
20
22
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28
60
56
PH1,PT1
PH1,PT1
XI
XI
H2
30
36
68
62
70
52
76
AS
DR

Fig. 10

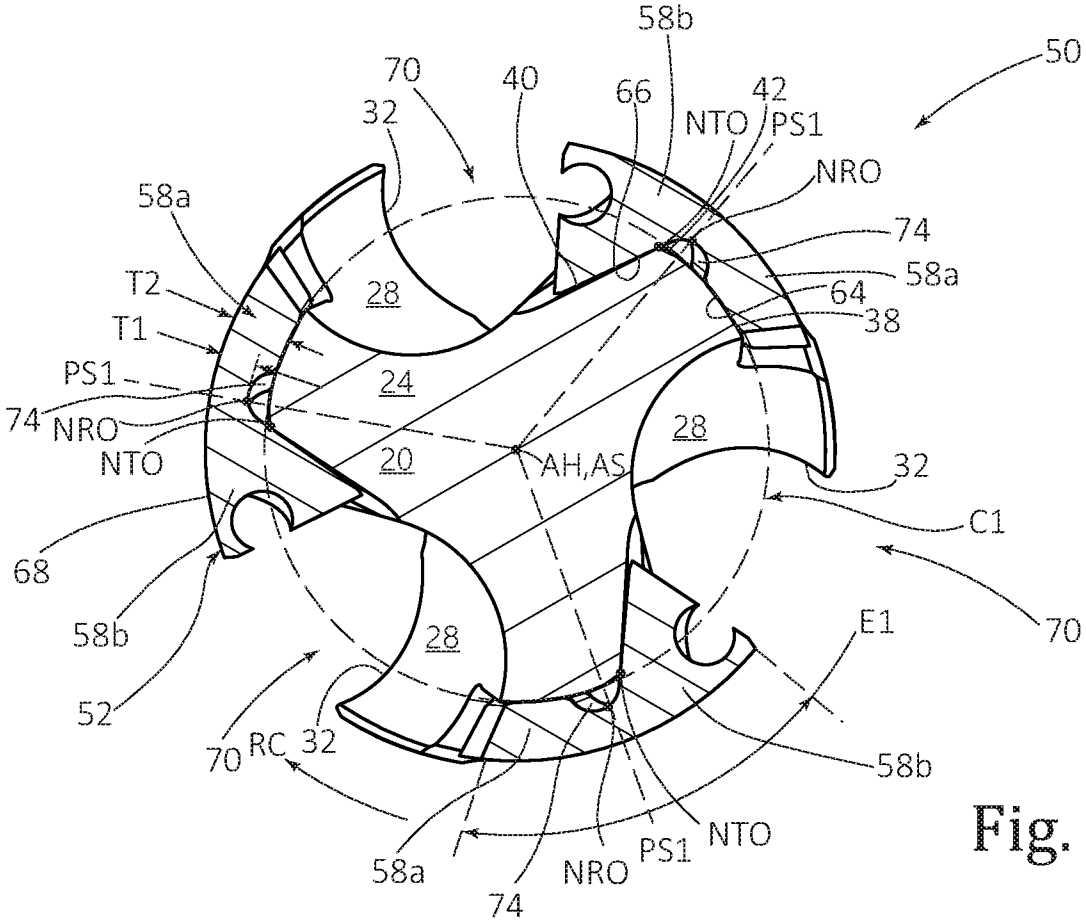

58b
50
70
40
66
42
32
NTO
PS1
NRO
58a
74
58a
T2
28
64
T1
38
PS1
24
74
NRO
28
NTO
20
AH,AS
32
C1
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58b
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E1
52
70
RC
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58b
58a
NRO
PS1
NTO
74

Fig. 11

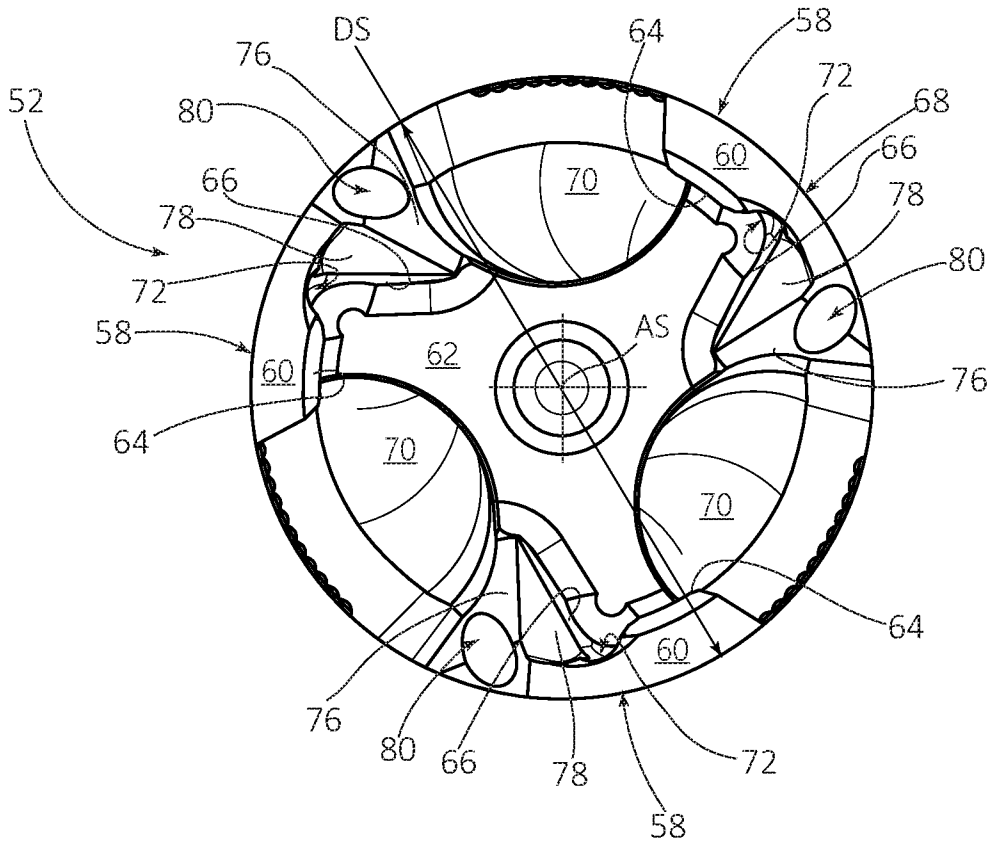

DS
64
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58
AS
62
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76
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76
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66
78
72
58

Fig. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2021/050468

A. CLASSIFICATION OF SUBJECT MATTER
INV. B23B51/02
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 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.
A	US 10 071 430 B2 (KENNAMETAL INC [US]) 11 September 2018 (2018-09-11) cited in the application column 8, line 8 - column 9, line 48; figures 1A, 1B, 2A - 2D	1-23

X,P A,P	WO 2020/141502 A1 (ISCAR LTD [IL]) 9 July 2020 (2020-07-09) claims 1-24; figures 1-8	1-7,10, 11,13-18 8,9,12, 19-23

A	US 2017/113282 A1 (ZEUG BERTHOLD HEINRICH [DE] ET AL) 27 April 2017 (2017-04-27) paragraph [0034] - paragraph [0041]; figures 1-3	1,15

A	WO 2014/091477 A1 (ISCAR LTD [IL]) 19 June 2014 (2014-06-19) page 7 - page 9; figures 1,2,3,4,10	1,15

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

☒ See patent family annex.

* Special categories of cited documents :

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"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
13 September 2021	21/09/2021

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	Prelovac, Jovanka

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IL2021/050468

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