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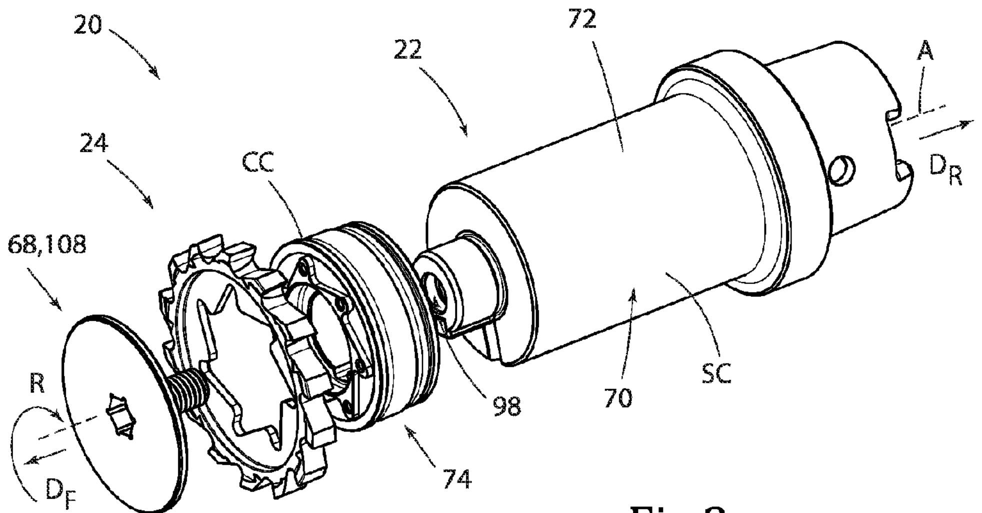

Fig.2

(57) Abrégé/Abstract:
A rotary milling tool (20) has a tool holder (22, 122) and a milling head (24) releasably attached thereto. The milling head (24) has a plurality of angularly spaced apart peripherally disposed cutting edges (32) which form an effective cutting edge (38). The milling head (24) has a head through recess (44) opening out to the head forward and rearward surfaces (26, 28). The recess (44) includes a centering region (52) and a driven region (54), the driven region (54) being axially forward of, and non-identical to, the centering region (52). The driven region (54) has at least one driven surface (58) facing opposite a rotational direction (R). The centering region (52) has at least one radially inwardly facing radial centering surface (62) located axially rearward of, and radially outward from, the at least one driven surface (58). The two opposing extremities (38a, 38b) of the effective cutting edge (38) define two parallel planes (PF, PR) respectively between which both the at least one driven surface (58) and the at least one radial centering surface (62) are disposed.

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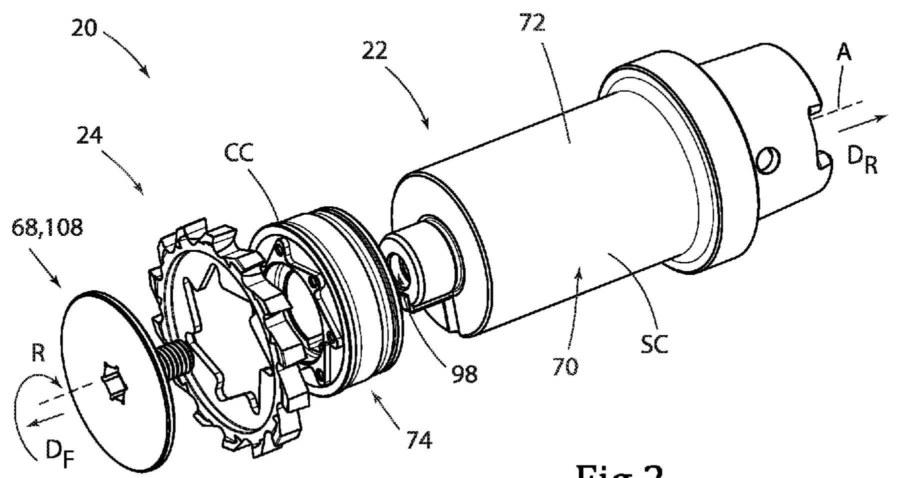

Fig.2

(57) **Abstract:** A rotary milling tool (20) has a tool holder (22, 122) and a milling head (24) releasably attached thereto. The milling head (24) has a plurality of angularly spaced apart peripherally disposed cutting edges (32) which form an effective cutting edge (38). The milling head (24) has a head through recess (44) opening out to the head forward and rearward surfaces (26, 28). The recess (44) includes a centering region (52) and a driven region (54), the driven region (54) being axially forward of, and non-identical to, the centering region (52). The driven region (54) has at least one driven surface (58) facing opposite a rotational direction (R). The centering region (52) has at least one radially inwardly facing radial centering surface (62) located axially rearward of, and radially outward from, the at least one driven surface (58). The two opposing extremities (38a, 38b) of the effective cutting edge (38) define two parallel planes (PF, PR) respectively between which both the at least one driven surface (58) and the at least one radial centering surface (62) are disposed.

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MILLING HEAD HAVING INTEGRALLY FORMED CUTTING EDGES AND ROTARY MILLING TOOL

FIELD OF THE INVENTION

The subject matter of the present application relates to rotary milling tools having a milling head with a plurality of peripherally disposed cutting edges integrally formed therewith, and in particular to such a milling head having at least one driven surface for torque transfer from a tool holder and at least one radial centering surface for radial alignment of milling head with said tool holder.

BACKGROUND OF THE INVENTION

Rotary milling tools can include a milling head releasably clamped to a tool holder by a fastening member, e.g. a retaining screw. The milling head can have a plurality of peripherally disposed cutting edges. The cutting edges can be integrally formed with the milling head. During assembly, the milling head can be radially centered on the tool holder (i.e. the milling head and the tool holder become co-axial) via radial alignment and centering surfaces located on the tool holder and milling head, respectively. Moreover, during cutting operations, torque is transferred from the tool holder to the milling head via driving and driven surfaces located on the tool holder and milling head, respectively.

A variety of such cutting tools and milling heads are disclosed in US 6,431,799 B1, US 6,571,451 B2, US 8,468,918 B2, US 9,751,138 B2, US 2007/0081873 A1, US 2018/0318941 A1 and WO 2010/021487.

SUMMARY OF THE INVENTION

In accordance with a first aspect of the subject matter of the present application there is provided a milling head having a head central axis that defines opposite forward and rearward directions and about which the milling head is rotatable in a rotational direction, the milling head comprising:

opposing head forward and rearward surfaces and a head peripheral surface extending therebetween, the head peripheral surface extending circumferentially about the head central axis;

a plurality of angularly spaced apart peripherally disposed cutting edges whose rotational loci in an axial half plane containing the head central axis define an effective cutting edge about the head central axis having axially spaced apart opposing cutting edge extremities which define an effective cutting edge length measured in the axial direction, each cutting edge being formed at the intersection of a rotationally forward rake surface and a rotationally rearward relief surface and being integrally formed with the milling head to have unitary one-piece construction therewith; and

a head through recess extending along the head central axis and opening out to the head forward and rearward surfaces, the head through recess being defined by a recess peripheral surface and comprising a centering region and a driven region, the driven region being axially forward of, and non-identical to, the centering region; wherein:

the recess peripheral surface at the driven region comprises at least one driven surface facing opposite the rotational direction;

the recess peripheral surface at the centering region comprises at least one radially inwardly facing radial centering surface located axially rearward of, and radially outward from, the at least one driven surface;

the two opposing extremities of the effective cutting edge define two parallel head forward and rearward planes respectively, the head forward and rearward planes being oriented perpendicularly to the head central axis and spaced apart by the effective cutting edge length; and

both the at least one driven surface and the at least one radial centering surface are disposed between the head forward and rearward planes.

In accordance with a second aspect of the subject matter of the present application there is provided a rotary milling tool comprising:

a milling head, of the type described above; and

a tool holder, having a holder central axis that defines opposite forward and rearward directions and about which the tool holder is rotatable in the rotational direction, the tool holder comprising:

a shank portion comprising a shank peripheral surface which extends circumferentially about the holder central axis; and

a coupling portion disposed at a forward end of the shank portion, the coupling portion comprising:

an alignment portion comprising a forward facing alignment forward surface bounded by an alignment peripheral surface which extends circumferentially about the holder central axis; and

a driving portion projecting forwardly from the alignment forward surface and comprising a forward facing driving forward surface bounded by a driving peripheral surface which extends circumferentially about the holder central axis; wherein:

the driving peripheral surface comprises at least one driving surface facing the rotational direction;

the alignment peripheral surface comprises at least one radially outwardly facing radial alignment surface located axially rearward of, and radially outward from, the at least one driving surface; wherein:

the milling head is releasably attached to the tool holder.

It is understood that the above-said is a summary, and that features described hereinafter may be applicable in any combination to the subject matter of the present application, for example, any of the following features may be applicable to the milling head and the rotary milling tool:

The milling head can comprise:

a plurality of angularly spaced apart cutting portions extending radially outwardly, each cutting edge being located at a respective cutting portion; and

a plurality of angularly spaced apart chip flutes which circumferentially alternate with the plurality of cutting portions along the head peripheral surface, each chip flute opening out to at least one of the head forward surface and the head rearward surface.

Each chip flute can open out to both the head forward surface and the head rearward surface.

Each cutting edge can extend across the head peripheral surface from the head forward surface to the head rearward surface.

Each cutting edge can extend continuously across the head peripheral surface.

The centering region can adjoin the head rearward surface.

The at least one radial centering surface can lie on an inner surface of an imaginary centering cylinder having an axis aligned with the head central axis.

The recess peripheral surface at the centering region can comprise exactly one radial centering surface which extends along an entire circumferential extent of the recess peripheral surface.

The recess peripheral surface can comprise at least one rearwardly facing axial bearing surface located axially between the at least one driven surface and the at least one radial centering surface.

The at least one axial bearing surface can be located radially between the at least one driven surface and the at least one radial centering surface.

The at least one axial bearing surface can be planar and oriented perpendicularly to the head central axis.

The recess peripheral surface can comprise exactly one axial bearing surface which extends along an entire circumferential extent of the recess peripheral surface.

No part of the milling head may extend beyond the head rearward plane in the rearward direction.

No part of the milling head may extend beyond the head forward plane in the forward direction.

The recess peripheral surface at the driven region can comprise at least one driven tooth projecting radially inwardly. Each of the at least one driven surfaces can be located on a respective driven tooth.

The at least one driven tooth can be mirror asymmetrical about all driven tooth axial half planes containing the head central axis and intersecting said at least one driven tooth.

The recess peripheral surface at the driven region can comprise a plurality of driven teeth angularly disposed about the head central axis.

The recess peripheral surface at the driven region can comprise N driven teeth, N being a positive integer. The milling head can exhibit N-fold rotational symmetry about the head central axis.

The recess peripheral surface can comprise at least one forwardly facing clamping surface located axially forward of the at least one driven surface.

The clamping surface can be located radially outward from the at least one driven surface.

The head through recess can comprise a fastening head receiving region which is axially forward of, and non-identical to, the driven region.

The fastening head receiving region can adjoins the head forward surface.

In axial view thereof, the milling head has a head circumscribed circle defined by the plurality of cutting edges and a head inscribed circle defined by radially innermost portions of the recess peripheral surface. The head circumscribed circle has a head circumscribed circle diameter and the head inscribed circle has a head inscribed circle diameter. The head inscribed circle diameter can be greater than a third of the head circumscribed circle diameter.

The alignment forward surface can comprise at least one forwardly facing axial support surface located axially between the at least one driving surface and the at least one radial alignment surface.

The tool holder can comprise a threaded bore opening out to the driving forward surface at a bore outlet opening.

The at least one driven surface of the milling head can abut the at least one driving surface of the coupling portion. The at least one radial centering surface of the milling head can abut the at least one radial alignment surface of the coupling portion.

On the milling head, the recess peripheral surface can comprise at least one rearwardly facing axial bearing surface located axially between the at least one driven surface and the at least one radial centering surface. On the coupling portion, the alignment forward surface can comprise at least one forwardly facing axial support surface located axially between the at least one driving surface and the at least one radial alignment surface. The at least one axial bearing surface can abut the at least one axial support surface.

The milling head can be releasably clamped to the tool holder by a fastening member located in the head through recess and threadingly engaged with the threaded bore.

The fastening member can comprise a fastening head. The fastening head can clampingly abut the milling head at the at least one clamping surface.

The fastening member may not extend beyond the head forward plane in the forward direction.

The fastening member can be an integrally formed retaining screw having unitary one-piece construction.

The external thread can comprise at least one unthreaded portion extending from both ends of the external thread so that the external thread is non-continuous. The threaded bore can be a through bore having a bore rear inlet opening. The bore rear inlet opening can be in fluid communication with the bore outlet opening via the at least one unthreaded portion.

BRIEF DESCRIPTION OF THE FIGURES

For a better understanding of the present application and to show how the same may be carried out in practice, reference will now be made to the accompanying drawings, in which:

Fig. 1 is a perspective view of a rotary milling tool, in accordance with the present application;

Fig. 2 is an exploded perspective view of the rotary milling tool shown in Fig. 1;

Fig. 3 is a perspective view of a milling head shown in Fig. 1;

Fig. 4 is a rearward end view of the milling head shown in Fig. 3;

Fig. 5 is a forward end view of the milling head shown in Fig. 3

Fig. 6 is an axial cross-sectional view of the milling head in Fig. 3, taken along line VI-VI in Fig. 5;

Fig. 7 is a detail of Fig. 6;

Fig. 8a-8c are three schematic diagrams taken in a head axial half-plane, showing each showing an effective cutting edge;

Fig. 9 is a forward end view of a coupling portion of a tool holder shown in Fig. 1;

Fig. 10 is an axial cross-sectional view of the coupling portion shown in Fig. 9, taken along line X-X in Fig. 9;

Fig. 11 is a perspective view of another tool holder, in accordance with the present application;

Fig. 12 is another perspective view of the tool holder shown in Fig. 11;

Fig. 13 is an axial cross-sectional view of the tool holder shown in Figs. 11 and 12;

Fig. 14 is a forward end view of the rotary milling tool shown in Fig. 1 without a fastening member;

Fig. 15 is an axial cross-sectional view of the rotary milling tool shown in Fig. 1;

Fig. 16 is an exploded perspective view of another rotary milling tool having the tool holder shown in Figs. 11 and 12, in accordance with the present application;

Fig. 17 is an axial cross-sectional view of the assembled rotary milling tool shown in Fig. 16; and

Fig. 18 is a perspective view of another rotary milling tool, having a rotary milling head not in accordance with the invention.

It will be appreciated that for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity, or several physical components may be included in one functional block or element. Further, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, various aspects of the subject matter of the present application will be described. For purposes of explanation, specific configurations and details are set forth in sufficient detail to provide a thorough understanding of the subject matter of the present application. However, it will also be apparent to one skilled in the art that the subject matter of the present application can be practiced without the specific configurations and details presented herein.

Attention is first drawn to Figs. 1 and 2, showing a rotary milling tool **20**, depicting an aspect of the present application. In this non-limiting example shown in the drawings, the rotary milling tool **20** can form a slot cutting tool suitable for slotting cutting operations. For example, the rotary milling tool **20** can be suitable for “T” slotting and/or Internal Groove Milling and/or Slitting. The rotary milling tool **20** has a tool central axis **A**. The rotary milling tool **20** has a tool holder **22, 122** which can be typically made from steel. The rotary milling tool **20** has a milling head **24** which can be typically made from cemented carbide. The milling head **24** is releasably attached to the tool holder **22, 122**.

It is noted that the term “slot cutting tool” as used herein may be replaced with other terms applicable in the metal cutting field for such cutting tools, for example, “slotting cutter”, , “slitting cutter”, “grooving cutter”, “slot mill cutter”, “groove cutting tool”, “side cutting tool”, “disc cutting tool”, and the like.

Reference is now made also to Figs. 3 to 8, showing another aspect of the subject matter of the present application, relating to the milling head **24**. The milling head **24** has a head central axis **B**. The head central axis **B** defines opposite forward and rearward directions $\mathbf{D_F}$**,** $\mathbf{D_R}$. The head central axis **B** forms an axis of rotation about which the milling head **24** is rotatable in a rotational direction **R**.

It should be appreciated that in the following discussion with regard to the milling head **24** use of the terms "forward" and "rearward" throughout the description and claims refer to a relative position in a direction of the head central axis **B** downwardly (or rearward direction $\mathbf{D_R}$) and upwardly (or forward directions $\mathbf{D_F}$), respectively, in Fig. 6. Moreover, the terms “axial” and “radial” are with respect to the head central axis **B**, unless specified otherwise.

As shown in Figs. 3 to 5, the milling head **24** includes opposing head forward and rearward surfaces **26, 28** and a head peripheral surface **30** which extends therebetween. The head forward surface **26** is axially forward of the head rearward surface **28**. The head peripheral surface **30** extends circumferentially about the head central axis **B**. Generally speaking, the head peripheral surface **30** faces radially outwardly. In accordance with some embodiments of the subject matter of the present application, as shown in Fig. 6, the milling head **24** can be shorter in the axial direction that in the radial direction. The milling head **24** can have a disc-like basic shape defined by the head forward and rearward surfaces **26, 28** and the head peripheral surface **30**.

The milling head **24** includes a plurality of cutting edges **32**. The plurality of cutting edges **32** are integrally formed with the milling head **24** to have unitary one-piece construction therewith. Thus, the periphery of the milling head **124** is devoid of replaceable cutting inserts. The plurality of cutting edges **32** are angularly spaced apart about the head central axis **B**. The plurality of cutting edges **32** are located at the head peripheral surface **30**. That is to say, the plurality of cutting edges **32** are peripherally disposed. Referring to Fig. 3, each cutting edge

32 is formed at the intersection of a rotationally forward rake surface **34** and a rotationally rearward relief surface **36**. In this non-limiting example shown in the drawings, generally speaking, each cutting edge **32** can extend in the axial direction. However, the each cutting edge **32** can be convex. In particular, each cutting edge **32** can include two sub-cutting edges that converge together to form a basic "V" shape (in a view in front of the rake surface). In accordance with some embodiments of the subject matter of the present application, each cutting edge **32** can extend continuously across the head peripheral surface **30** in the axial direction. Each cutting edge **32** can extend across the entire axial extent of the head peripheral surface **30** (i.e. from the head forward surface **26** to the head rearward surface **28**).

As is known in the art, the plurality of cutting edges **32** can be aligned in the axial direction (as disclosed in US 2018/0318941 A1, e.g. see Fig. 4). Alternatively, as is also known in the art, the plurality of cutting edges **32** the cutting edges **32** can be offset in the axial direction (as disclosed, for example, in US 6,431,799 B1 and US 8,468,918 B2, where circumferentially alternate cutting edges **32** form two sets of axially offset cutting edges **32**). Each of the plurality of cutting edges **32** form a rotational locus about the head central axis **B**. The rotational loci of the plurality of cutting edges **32** can be partly or fully co-incident with each other. The rotational loci of the plurality of cutting edges **32** can intersect with each other. The rotational loci of the plurality of cutting edges **32** generate a corresponding outer envelope of a body of revolution as the rotary milling tool **20** rotates around the head central axis **B** by 360°. To exemplify the foregoing reference is made to Figs. 8a-8c, representing three non-limiting examples showing the rotational loci of a first and a second cutting edge **32a, 32b** in a head axial half plane containing the head central axis **B**, in accordance with the invention. In Fig. 8a, the rotational loci are fully co-incident. In Fig. 8b, the rotational loci intersect with each other. In Fig. 8c, the rotational loci are partly co-incident. It is noted that the cutting head **24**, in accordance with the invention, is not limited to two cutting edges. In the head axial half plane, the rotational loci of the plurality of cutting edges **32** define an effective cutting edge **38**. The effective cutting edge **38** has an effective cutting edge length **L** measured in the axial direction. For slot cutting tools, the effective cutting edge **38** extends continuously across the entire axial extent of the periphery of the milling head **24**. The effective cutting edge length **L** defines the width of a slot cut in a work piece when the milling head **24** rotates in the rotational direction **R** and enters the work piece.

The effective cutting edge **38** includes two axially spaced apart opposing extremities **38a**, **38b**, between which the effective cutting edge **38** extends. The two opposing extremities **38a, 38b** define the effective cutting edge length **L**. The two opposing extremities **38a**, **38b** of the effective cutting edge **38** define parallel head forward and rearward planes **PF, PR** respectively. The head forward and rearward planes **PF, PR** are oriented perpendicularly to the head central axis **B** and spaced apart by the effective cutting edge length **L**. The milling head **24** has a head median plane **M** parallel to the head forward and rearward planes **PF, PR** and located midway therebetween.

Referring to Figs. 4 and 5, the milling head **24** includes a plurality of angularly spaced apart cutting portions **40** which extend radially outwardly. Each cutting edge **32** is located at a respective cutting portion **40**. The milling head **24** includes a plurality of angularly spaced apart chip flutes **42**, for chip evacuation. The plurality of chip flutes **42** circumferentially alternate with the plurality of cutting portions **40** along the head peripheral surface **30**. In accordance with some embodiments of the subject matter of the present application, each chip flute **42** can open out to at least one of the head forward surface **26** and the head rearward surface **28**. Each chip flute **42** can open out to both the head forward surface **26** and the head rearward surface **28**.

The milling head **24** includes a head through recess **44** which opens out to the head forward and rearward surfaces **26, 28**. The head through recess **44** extends along the head central axis **B**. Stated differently, the head central axis **B** passes through the head through recess **44**. Thus, the milling head **24,** can be crown-like. The head through recess **44** is defined by a recess peripheral surface **46**. The recess peripheral surface **46** extends circumferentially about the head central axis **B**. Generally speaking, the recess peripheral surface **46** faces radially inwardly. Referring to Fig.4, in an axial view thereof, the milling head **24** has a head circumscribed circle **CCC** (centered at the head central axis **B**) defined by the plurality of cutting edges **32.** The head circumscribed circle **CCC** has a head circumscribed circle diameter **CCD**. The milling head **24** has a head inscribed circle **IC** (centered at the head central axis **B**) defined by the radially innermost portions of the recess peripheral surface **46**. The head inscribed circle **IC** has a head inscribed circle diameter **ICD**. The head inscribed circle diameter **ICD** can be greater than a third of the head circumscribed circle diameter **CCD**. Advantageously this reduces the amount of material required to manufacture the milling head **24.**

Referring in particular to Fig. 6, showing an axial cross-sectional view of the milling head **24** through a driven surface **58**, and Fig. 7, showing a detail of Fig. 6. In accordance with some embodiments of the subject matter of the present application, the head forward surface **26** can include a head forward central surface **48** which surrounds and adjoins the head through recess **44**. The head forward central surface **48** can be planar and perpendicular to the head central axis **B**. The head rearward surface **28** can include a head rearward central surface **50** which surrounds and adjoins the head through recess **44**. The head rearward central surface **50** can be planar and perpendicular to the head central axis **B**. The head forward and rearward central surfaces **48, 50** can be parallel with each other. As shown in fig. 7, the head forward and rearward central surfaces **48, 50** can be located within the head forward and rearward planes **PF, PR**. The cutting portions **40** and chip flutes **42** can extend inwardly to the head forward and rearward central surfaces **48, 50**.

As seen in Figs. 6 and 7, the head through recess **44** does not extend uniformly along the head central axis **B**. The head through recess **44** includes two axially offset regions, a centering region **52** and a driven region **54.** The driven region **54** is axially forward of the centering region **52**. The recess peripheral surface **46** at the driven region **54** defines a boundary which is different than the boundary defined by the recess peripheral surface **46** at the centering region **52**. Thus, the centering region **52** and the driven region **54** are non-identical. In accordance with some embodiments of the subject matter of the present application, the centering region **52** can have a constant cross section in a radial plane along the head central axis **B**. The driven region **54** can have a constant cross section in a radial plane along the head central axis **B**, different to the cross section of the centering region **52**.

As shown in Fig 7, as measured in the axial direction, the centering region **44** has a centering region height **HC** and the driven region **54** has a driven region height **HD**. In accordance with some embodiments of the subject matter of the present application, the driven region height **HD** can be equal to the centering region height **HC**. The centering region **52** can adjoin the head rearward surface **28**. The head through recess **44** can include a third axially offset region, namely a fastening head receiving region **56**. The fastening head receiving region **56** is axially forward of the driven region **54**. The fastening head receiving region **56** can be non-identical to driven region **54**. The fastening head receiving region **56** can be non-identical to centering region **52**. Thus, the milling head **24** can be mirror asymmetrical about the head median plane **M**. The fastening head receiving region **56** can be wider than the driven region **54** in the radial direction. As shown in Fig. 7, as measured in the axial direction, the fastening head receiving region **56** has a fastening head receiving region height **HF**. The fastening head receiving region height **HF** can be equal to the driven region height **HD**. The fastening head receiving region **56** can adjoin the head forward surface **26**. It is noted that in an end view of the milling head **24**, the see though part of the through recess **44** is formed by the driven region **54**, and not by the centering region **52** nor by the fastening head receiving region if present **56**.

The recess peripheral surface **46** at the driven region **54** includes at least one driven surface **58** which faces opposite the rotational direction **R**. The at least one driven surface **58** is configured for torque transfer from a corresponding surface on the tool holder **22, 122**. The at least one driven surface **58** is disposed between the head forward and rearward planes **PF, PR**. The at least one driven surface **58** can be planar and extend in an axial plane of the milling head **24** which contains the head central axis **B.**

Reference is made to Fig. 7. In accordance with some embodiments of the subject matter of the present application, the recess peripheral surface **46** at the driven region **54** can include at least one driven tooth **60** which projects radially inwardly. The at least one driven tooth **60** includes two opposing forward and rearward driven tooth side walls **61a, 61b**, respectively, which define the at least one driven tooth **60** in the axial direction. The fastening head receiving region **56** and the driven region **54** can be delimited by an upper plane **UP** defined by the forward driven tooth side walls **61a**. The centering region **52** and the driven region **54** can be delimited by a lower plane defined by the rearward driven tooth side walls **61b**. The driven region **54** can be radially inwards of than the centering region **52** in all radial directions. Each of the at least one driven surfaces **58** can be located on a respective driven tooth **60**. Referring to Fig. 4, the at least one driven teeth **60** can be mirror asymmetrical about all driven tooth axial half planes **HP1** which contain the head central axis **B** and intersect the said at least one driven teeth **60**. Such a configuration can prevent the milling head **24** from inadvertently being reversed. (That is to say, the milling head **24** cannot be attached to the tool holder **22, 122** when flipped over 180° about an axis perpendicular to the head central axis **B** contained in the driven tooth axial half planes **HP1**). The recess peripheral surface **46** at the driven region **54** can include a plurality of driven teeth **60** angularly disposed about the head central axis **B**. The recess peripheral surface **46** at the driven region **54** can include N driven teeth **60**, N being a positive integer. The milling head **24** can exhibit N-fold rotational symmetry about the head central axis **B**.

The recess peripheral surface **46** at the centering region **52** includes at least one radial centering surface **62** which faces radially inwardly. The at least one radial centering surface **62** is located axially rearward of the at least one driven surface **58**. The at least one radial centering surface **62** is located radially outward from the at least one driven surface **58**. The at least one radial centering surface **62** is disposed between the head forward and rearward planes **PF, PR**.

Referring to Figs. 10 and 13, in accordance with some embodiments of the subject matter of the present application, the at least one radial centering surface **62** can lie on an inner surface of an imaginary centering cylinder having an axis aligned with the head central axis **B**. The recess peripheral surface **46** at the centering region **52** can include exactly one radial centering surface **62** which extends along an entire circumferential extent of the recess peripheral surface **46**.

In accordance with some embodiments of the subject matter of the present application, the recess peripheral surface **46** can include at least one rearwardly facing axial bearing surface **64**. The at least one axial bearing surface **64** is designed to locate the milling head **24** in a predetermined axial position with respect to the tool holder **22, 122**. The at least one axial bearing surface **64** can be formed on the recess peripheral surface **46** at the centering region **52** adjacent the driven region **54**. The at least one axial bearing surface **64** can be located axially between the at least one driven surface **58** and the at least one radial centering surface **62**. It is noted that the at least one axial bearing surface **64** is formed in a through recess and not on a side (non-recessed) surface of the milling head **24** (as disclosed in e.g. JP2006281371). The at least one axial bearing surface **64** can be located between the head forward and rearward planes **PF, PR**. The at least one axial bearing surface **64** can be located radially between the at least one driven surface **58** and the at least one radial centering surface **62**. The at least one axial bearing surface **64** can be planar and oriented perpendicularly to the head central axis **B**. Referring to Fig 7, the at least one axial bearing surface **64** can be formed on a circular bearing projection **65** projecting rearwardly from the rearward driven tooth side wall **61b**. The recess peripheral surface **46** can include exactly one axial bearing surface **64** which extends along an entire circumferential extent of the recess peripheral surface **46**.

In accordance with some embodiments of the subject matter of the present application, the recess peripheral surface **46** can include at least one forwardly facing clamping surface **66** for clamping abutment with a fastening member **68**, as described later on in the description. The at least one clamping surface **66** can be formed on the recess peripheral surface **46** at the fastening head receiving region **56** adjacent the driven region **54**. The clamping surface **66** can be located axially forward of the at least one driven surface **58**. The clamping surface **66** can be located radially outward from the at least one driven surface **58**.

In accordance with some embodiments of the subject matter of the present application, no part of the milling head **24** can extend beyond the head rearward plane **PR** in the rearward direction $\mathbf{D_R}$. Thus, the milling head **24** is devoid of any projection projecting rearwardly from the head rearward plane **PR** as disclosed in, for example, US 8,708,611. Similarly, no part of the milling head **24** can extend beyond the head forward plane **PF** in the forward direction $\mathbf{D_F}$ (and thus, the effective cutting edge length **L** can define the maximum axial dimension of the milling head **24** as measured in the axial direction). Advantageously, this reduces the amount of material required to manufacture the milling head **24,** which is particularly important for large milling heads.

Thus, as seen in the figures, the head recess **44** comprises a toothed hub **44** provided with a plurality of circumferentially spaced apart, radially inwardly projecting, mirror-asymmetric driven teeth **60** with driven surfaces **58**, a stepped arrangement comprising a radially inwardly facing centering surface **62** and a rearwardly facing recessed axial bearing surface **64** on a rearward facing side of the hub **44**, and a recessed forwardly facing clamping surface **66** on a forward facing side of the hub **44**.

Reference is now made to Figs. 9 to 13, depicting the tool holder **22, 122**. The tool holder **22, 122** has a holder central axis **C**. The holder central axis **C** extends in the forward and rearward directions $\mathbf{D_F}$**,** $\mathbf{D_R}$. The holder central axis **C** forms an axis of rotation about which the tool holder **22, 122** is rotatable in the rotational direction **R**.

It should be appreciated that in the following discussion with regard to the tool holder **22, 122**, use of the terms "forward" and "rearward" throughout the description and claims refer to a relative position in a direction of the holder central axis **C** downwardly and upwardly, respectively, in Fig. 10. Moreover, the terms “axial” and “radial” are with respect to the holder central axis **C**, unless specified otherwise.

The tool holder **22**, **122** includes a shank portion **70**. The shank portion **70** includes a shank peripheral surface **72** which extends circumferentially about the holder central axis **C**. In accordance with some embodiments of the subject matter of the present application, the shank portion **70** can be elongated in the axial direction.

The tool holder **22**, **122** also includes a coupling portion **74**. The coupling portion **74** is disposed at a forward end of the shank portion **70**. In accordance with some embodiments of the subject matter of the present application, the shank portion **70** and the coupling portion **74** can be separable from each other so that the tool holder **22** has a modular construction (see Figs. 1 and 2). In such a configuration the coupling portion **74** includes a coupling portion through hole **73**, which allows passage of the fastening member to a threaded bore as described hereinafter. In accordance with some other embodiments of the subject matter of the present application, the shank portion **70** and the coupling portion **74** can be integrally formed together so that the tool holder **122** has a unitary, one-piece construction (see Figs. 11 and 12).

Referring to Figs. 2 and 12, the shank peripheral surface **72** adjoining the coupling portion **74** defines an imaginary shank cylinder **SC** having an axis aligned with the holder central axis **C**. The imaginary shank cylinder **SC** has a shank outer diameter **ODs**. In this non-limiting example shown in the drawings, the shank peripheral surface **72** adjoining the coupling portion **74** can lie entirely on the imaginary shank cylinder **SC**. The entire shank peripheral surface **72** can lie on the imaginary shank cylinder **SC**. In accordance with some embodiments of the subject matter of the present application, the coupling portion **74** can exhibit rotational symmetry about the holder central axis **C**.

The coupling portion **74** includes an alignment portion **76**. The alignment portion **76** includes a forward facing alignment forward surface **78**. The alignment forward surface **78** is bounded by an alignment peripheral surface **80**. The alignment peripheral surface **80** extends circumferentially about the holder central axis **C**.

Referring to Fig. 10, the coupling portion **74** can optionally include an extension portion **83** extending rearwardly from the alignment portion **76**. The extension portion **83** includes an extension peripheral surface **83a** which extends circumferentially about the holder central axis **C**. As shown in Fig. 1, the extension portion **83** can be flush with the shank portion **70**. Stated differently, the extension peripheral surface **83a** and the shank peripheral surface **72** transition smoothly and continuously with each other. The alignment portion **76** has substantially the same radial dimension as the extension portion **83** and thus the shank portion **70.**

Alternately, in the non-limiting example shown in Figs. 11-13, the tool holder **122** can be devoid of the extension portion **83**. The alignment portion **76** can extend radially outwards beyond the shank portion **70**. Stated differently, tool holder **122** can have a flanged configuration provided by the alignment portion **76** (i.e. the tool holder **122** is “flanged”). Preferably, the alignment portion **76** can extend radially outwards beyond the shank portion **70** about the entire circumferential extent of the shank portion **70**.

In the flanged configuration of the tool holder **122**, the alignment portion **76** can further include a rearward facing alignment rearward surface **82**, opposite the alignment forward surface **78** (see Fig. 13). The alignment peripheral surface **80** can extend between the alignment forward and rearward surfaces **78, 82**. The alignment portion **76** can have a disc-like basic shape defined by the alignment forward and rearward surfaces **78, 82** and the alignment peripheral surface **80**.

The coupling portion **74** also includes a driving portion **84**. The driving portion **84** projects forwardly from the alignment forward surface **78**. The alignment forward surface **78** defines a boundary between the alignment portion **76** and the driving portion **84**. The driving portion **84** can be radially inwards of the alignment portion **76** in all radial directions. The driving portion **84** includes a forward facing driving forward surface **86** bounded by a driving peripheral surface **88**. The driving peripheral surface **88** extends circumferentially about the holder central axis **C**.

Referring to Figs. 9 and 11, the driving peripheral surface **88** includes at least one driving surface **90** which faces the rotational direction **R**. When the tool holder **22, 122** rotates about the holder central axis **C** torque is transferred to the milling head **24** via the driving surfaces. The at least one driving surface **90** can be planar and extend in an axial plane of the tool holder **22, 122** which contains the holder central axis **B.**

In the flanged configuration of the tool holder **122**, the at least one driving surface **90** can be located on the coupling portion **74** so that it is disposed outside the imaginary shank cylinder **SC** (see Fig. 13). Advantageously, this increases the torque (for the same force) by virtue of the increased distance from the axis of rotation. Moreover, the flanged configuration of the tool holder **122** is advantageous for tool holders having a small shank outer diameter with limited area for the provision of a driving mechanism.

Referring to Figs. 9 and 11, in accordance with some embodiments of the subject matter of the present application, the driving portion **84** can include at least one driving tooth **92** which extends radially outwardly. Each of the at least one driving surfaces **90** can be located on a respective driving tooth **92**. Referring specifically to Fig. 9, the at least one driving teeth **92** can be mirror asymmetrical about all driving tooth axial half planes **HP2** which contain the holder central axis **C** and intersect said at least one driving teeth **92**. The driving portion **84** can include a plurality of driving teeth **92** angularly disposed about the holder central axis **C**. The adjacent pairs of driving teeth **92** can be spaced apart by a driving tooth gap **93**. As seen in Figs. 9 and 11, a coupling portion **74** may have six or more driving teeth **92**, though other numbers of driving teeth **92** are also contemplated.

Referring to Figs. 10 and 13, the alignment peripheral surface **80** includes at least one radial alignment surface **94** which faces radially outwardly. The at least one radial alignment surface **94** is located axially rearward of the at least one driving surface **90**. The at least one radial alignment surface **94** is located radially outward from the at least one driving surface **90**. The at least one radial alignment surface **94** can lie on an outer surface of an imaginary alignment cylinder **AC** having an axis aligned with the holder central axis **C**. The alignment cylinder **AC** has an alignment outer diameter $\mathbf{OD_A}$. The alignment peripheral surface **80** can include exactly one radial alignment surface **94** which extends along an entire circumferential extent of the alignment peripheral surface **80**. Referring to Fig. 13, in the flanged configuration of the tool holder **122**, the at least one radial alignment surface **94** can adjoin the alignment rearward surface **82**. The at least one radial alignment surface **94** can be located on the coupling portion **74** so that it is disposed outside the imaginary shank cylinder **SC** (See Fig. 13).

In the non-flanged configuration, the alignment outer diameter $\mathbf{OD_A}$ can be substantially equal to the shank outer diameter $\mathbf{OD_S}$. In the flanged configuration, the alignment outer diameter $\mathbf{OD_A}$ can be greater than the shank outer diameter $\mathbf{OD_S}$ (i.e. $\mathbf{OD_A} > \mathbf{OD_S}$). In accordance with some embodiments of the subject matter of the present application, the alignment outer diameter $\mathbf{OD_A}$ can be greater than twice the shank outer diameter $\mathbf{OD_S}$.

In accordance with some embodiments of the subject matter of the present application, the alignment forward surface **78** can include at least one forwardly facing axial support surface **96**. The at least one axial support surface **96** can be located axially between the at least one driving surface **90** and the at least one radial alignment surface **94**. The at least one axial support surface **96** can be located radially between the at least one driving surface **90** and the at least one radial alignment surface **94**. The at least one axial support surface **96** can be planar and oriented perpendicularly to the holder central axis **C**. The at least one axial support surface **96** can be adjacent the alignment peripheral surface **96**. The alignment forward surface **78** can include exactly one axial support surface **96** which extends along an entire circumferential extent of the alignment forward surface **78**.

In accordance with some embodiments of the subject matter of the present application, the tool holder **22, 122** can include a threaded bore **98** which opens out to the driving forward surface **86** at a bore outlet opening **98a**. The threaded bore **98** is for threadingly receiving the fastening member **68** as discussed hereinafter. In accordance with some embodiments of the subject matter of the present application, the threaded bore **98** can extend along the holder central axis **C** and thus be centrally located. The driven teeth **60** can be arranged about the bore outlet opening **98a**. The threaded bore **98** can be a through bore having a bore rear inlet opening **98b**.

Reverting to Figs. 1, 2 and 16, the milling head **24** is releasably clamped to the tool holder **22, 122** by the fastening member **68** to form an assembled state of the rotary milling tool **20**. As shown in Fig. 16, the fastening member **68** includes a fastening head **100** and a male member **102** projecting therefrom. The male member **102** includes an external thread **104**. In accordance with some embodiments of the subject matter of the present application, the fastening member **68** can be an integrally formed retaining screw **108** having unitary one-piece construction. The external thread **104** can include at least one unthreaded portion **106** which extends from both ends of the external thread **104** so that the external thread **104** is non-continuous. The bore rear inlet opening **98b** can be in fluid communication with the bore outlet opening **98a** via the at least one unthreaded portion **106**. Thus, cooling fluid can be directed onto the plurality of cutting edges **32**.

Reference is now made to 13, 14 and 16. In the assembled position of the rotary milling tool **20**, the fastening member **68** is located in the head through recess **44** and threadingly engaged with the threaded bore **98**. Making reference in particular to Figs. 14 and 15, the at least one driven surface **58** abuts the at least one driving surface **90**. The at least one radial centering surface **62** abuts the at least one radial alignment surface **94**. In accordance with some embodiments of the subject matter of the present application, the driven teeth **60** can be located in the driving tooth gaps **93**. The at least one axial bearing surface **64** can abut the at least one axial support surface **96**. The fastening member **68** can clampingly abut the milling head **24** at the at least one clamping surface **66**. The fastening member **68** (specifically the fastening head **100**) may not extend beyond the head forward plane **PF** in the forward direction $\mathbf{D_F}$.

In the assembled position of the rotary milling tool **20**, the milling head **24** and the tool holder **22, 122** are co-axial. Stated differently, the head central axis **B** and the holder central axis **C** are co-incident with the tool central axis **A**.

Reference is now made to Fig. 18, showing a cutting tool **120** having a milling head **124** in which the plurality of cutting edges **132** are formed on separate cutting inserts **110** that are releasably attached to the milling head **124**. The milling head 1**24** can form a face milling cutting tool **120** suitable for face milling cutting operations. The cutting inserts **110** can be arranged in a single axial row. In milling head **124**, the effective cutting edge does not extend continuously across the entire axial extent of the periphery of the milling head **124.** Its effective cutting edge length defines the depth of cut in a work piece when the milling head **124** rotates in the rotational direction **R** and enters the work piece. It is noted that such a milling head **124** can be releasably attached to tool holders similar to the tool holders **122, 22** described above (i.e. having a flanged or non-flanged configuration), so long as the milling head **124** is provided with appropriate driven teeth, not unlike those described above.

It is noted that the rotary cutting tools **20**, **120** shown in Figs. 16 and 18, respectively, and the tool holder **122** provided therewith (as shown in Figs. 11-13, i.e. having the flanged configuration) rotates in the opposite rotational direction than that of the tool holder **22** shown, for example, in Figs. 1 and 2 (i.e. having the non-flanged configuration).

Although the subject matter of the present application 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

1. A milling head (24) having a head central axis (B) that defines opposite forward and rearward directions (D_F, D_R) and about which the milling head (24) is rotatable in a rotational direction (R), the milling head (24) comprising:

opposing head forward and rearward surfaces (26, 28) and a head peripheral surface (30) extending therebetween, the head peripheral surface (30) extending circumferentially about the head central axis (B);

a plurality of angularly spaced apart peripherally disposed cutting edges (32) whose rotational loci in a head axial half plane containing the head central axis (B) define an effective cutting edge (38) having axially spaced apart opposing cutting edge extremities (38a, 38b) which define an effective cutting edge length (L) measured in the axial direction, each cutting edge (32) being formed at the intersection of a rotationally forward rake surface (34) and a rotationally rearward relief surface (36) and being integrally formed with the milling head (24) to have unitary one-piece construction therewith; and

a head through recess (44) extending along the head central axis (B) and opening out to the head forward and rearward surfaces (26,28), the head through recess (44) being defined by a recess peripheral surface (46) and comprising a centering region (52) and a driven region (54), the driven region (54) being axially forward of, and non-identical to, the centering region (52); wherein:

the recess peripheral surface (46) at the driven region (54) comprises at least one driven surface (58) facing opposite the rotational direction (R);

the recess peripheral surface (46) at the centering region (52) comprises at least one radially inwardly facing radial centering surface (62) located axially rearward of, and radially outward from, the at least one driven surface (58);

the two opposing extremities (38a, 38b) of the effective cutting edge (38) define two parallel head forward and rearward planes (PF, PR) respectively, the head forward and rearward planes (PF, PR) being oriented perpendicularly to the head central axis (B) and spaced apart by the effective cutting edge length (L); and

both the at least one driven surface (58) and the at least one radial centering surface (62) are disposed between the head forward and rearward planes (PF, PR).

2. The milling head (24), according to claim 1, wherein, the milling head (24) comprises:

a plurality of angularly spaced apart cutting portions (40) extending radially outwardly, each cutting edge (32) being located at a respective cutting portion (40); and

a plurality of angularly spaced apart chip flutes (42) which circumferentially alternate with the plurality of cutting portions (40) along the head peripheral surface (30), each chip flute (42) opening out to at least one of the head forward surface (26) and the head rearward surface (28).

3. The milling head (24), according to claim 2, wherein each chip flute (42) opens out to both the head forward surface (26) and the head rearward surface (28).

4. The milling head (24), according to any one of claims 1-3, wherein each cutting edge (32) extends across the head peripheral surface (30) from the head forward surface (26) to the head rearward surface (28).

5. The milling head (24), according to any one of claims 1-4, wherein each cutting edge (32) extends continuously across the head peripheral surface (30).

6. The milling head (24), according to any one of claims 1-5, wherein the centering region (52) adjoins the head rearward surface (28).

7. The milling head (24), according to any one of claims 1-6, wherein the at least one radial centering surface (62) lies on an inner surface of an imaginary centering cylinder (CC) having an axis aligned with the head central axis (B).

8. The milling head (24), according to any one of claims 1-7, wherein the recess peripheral surface (46) at the centering region (52) comprises exactly one radial centering surface (62) which extends along an entire circumferential extent of the recess peripheral surface (46).

9. The milling head (24), according to any one of claims 1-8, wherein the recess peripheral surface (46) comprises at least one rearwardly facing axial bearing surface (64) located axially between the at least one driven surface (58) and the at least one radial centering surface (62).

10. The milling head (24), according to claim 9, wherein the at least one axial bearing surface (64) is located radially between the at least one driven surface (58) and the at least one radial centering surface (62).

11. The milling head (24), according to claims 9 or 10, wherein the at least one axial bearing surface (64) is planar and oriented perpendicularly to the head central axis (B).

12. The milling head (24), according to any one of claims 9-11, wherein the recess peripheral surface (46) comprises exactly one axial bearing surface (64) which extends along an entire circumferential extent of the recess peripheral surface (46).

13. The milling head (24), according to any one of claims 1-12, wherein no part of the milling head (24) extends beyond the head rearward plane (PR) in the rearward direction (D_R).

14. The milling head (24), according to any one of claims 1-13, wherein no part of the milling head (24) extends beyond the head forward plane (PF) in the forward direction (D_F).

15. The milling head (24), according to any one of claims 1-14, wherein:

the recess peripheral surface (46) at the driven region (54) comprises at least one driven tooth (60) projecting radially inwardly; and

each of the at least one driven surfaces (58) is located on a respective driven tooth (60).

16. The milling head (24), according to claim 15, wherein the at least one driven tooth (60) is mirror asymmetrical about all driven tooth axial half planes (HP1) containing the head central axis (B) and intersecting said at least one driven tooth (60).

17. The milling head (24), according to claims 15 or 16, wherein the recess peripheral surface (46) at the driven region (54) comprises a plurality of driven teeth (60) angularly disposed about the head central axis (B).

18. The milling head (24), according to any one claims 1-17, wherein:

the recess peripheral surface (46) at the driven region (54) comprises an integer number N driven teeth (60); and

the milling head (24) exhibits N-fold rotational symmetry about the head central axis (B).

19. The milling head (24), according to any one of claims 1-18, wherein the recess peripheral surface (46) comprises at least one forwardly facing clamping surface (66) located axially forward of the at least one driven surface (58).

20. The milling head (24), according to claim 19, wherein the clamping surface (66) is located radially outward from the at least one driven surface (58).

21. The milling head (24), according to any one of claims 1-20, wherein the head through recess (44) comprises a fastening head receiving region (56) which is axially forward of, and non-identical to, the driven region (54).

22. The milling head (24), according to claim 21, wherein the fastening head receiving region (56) adjoins the head forward surface (26).

23. The milling head (24), according to any one of claims 1-22, wherein:

in axial view thereof, the milling head (24) has a head circumscribed circle (CCC) defined by the plurality of cutting edges (32) and a head inscribed circle (IC) defined by radially innermost portions of the recess peripheral surface (46);

the head circumscribed circle (CCC) has a head circumscribed circle diameter (CCD) and the head inscribed circle (IC) has a head inscribed circle diameter (ICD); and

the head inscribed circle diameter (ICD) is greater than a third of the head circumscribed circle diameter (CCD).

24. A rotary milling tool (20) comprising:

a milling head (24), in accordance with any one of claims 1-23; and

a tool holder (22, 122), having a holder central axis (C) that defines opposite forward and rearward directions (D_F, D_R) and about which the tool holder (22, 122) is rotatable in the rotational direction (R), the tool holder (22, 122) comprising:

a shank portion (70) comprising a shank peripheral surface (72) which extends circumferentially about the holder central axis (C); and

a coupling portion (74) disposed at a forward end of the shank portion (70), the coupling portion (74) comprising:

an alignment portion (76) comprising a forward facing alignment forward surface (78) bounded by an alignment peripheral surface (80) which extends circumferentially about the holder central axis (C); and

a driving portion (84) projecting forwardly from the alignment forward surface (78) and comprising a forward facing driving forward surface (86) bounded by a driving peripheral surface (88) which extends circumferentially about the holder central axis (C); wherein:

the driving peripheral surface (88) comprises at least one driving surface (90) facing the rotational direction (R);

the alignment peripheral surface (80) comprises at least one radially outwardly facing radial alignment surface (94) located axially rearward of, and radially outward from, the at least one driving surface (90); wherein:

the milling head (24) is releasably attached to the tool holder (22, 122).

25. The rotary milling tool (20), according to claim 24, wherein:

the at least one driven surface (58) of the milling head (24) abuts the at least one driving surface (90) of the coupling portion (74); and

the at least one radial centering surface (62) of the milling head (24) abuts the at least one radial alignment surface (94) of the coupling portion (74).

26. The rotary milling tool (20), according to claim 25, wherein:

on the milling head (24), the recess peripheral surface (46) comprises at least one rearwardly facing axial bearing surface (64) located axially between the at least one driven surface (58) and the at least one radial centering surface (62);

on the coupling portion (74), the alignment forward surface (78) comprises at least one forwardly facing axial support surface (96) located axially between the at least one driving surface (90) and the at least one radial alignment surface (94); and

the at least one axial bearing surface (64) abuts the at least one axial support surface (96).

27. The rotary milling tool (20), according to any one of claims 24-26, wherein:

the tool holder (22, 122) comprises a threaded bore (98) opening out to the driving forward surface (86) at a bore outlet opening (98a); and

the milling head (24) is releasably clamped to the tool holder (22, 122) by a fastening member (68) located in the head through recess (44) and threadingly engaged with the threaded bore (98).

28. The rotary milling tool (20), according to claim 27, wherein:

the recess peripheral surface (46) comprises at least one forwardly facing clamping surface (66) located axially forward of the at least one driven surface (58);

the fastening member (68) comprises a fastening head (100); and

the fastening head (100) clampingly abuts the milling head (24) at the at least one clamping surface (66).

29. The rotary milling tool (20), according to claims 27 or 28, wherein the fastening member (68) is an integrally formed retaining screw (108) having unitary one-piece construction.

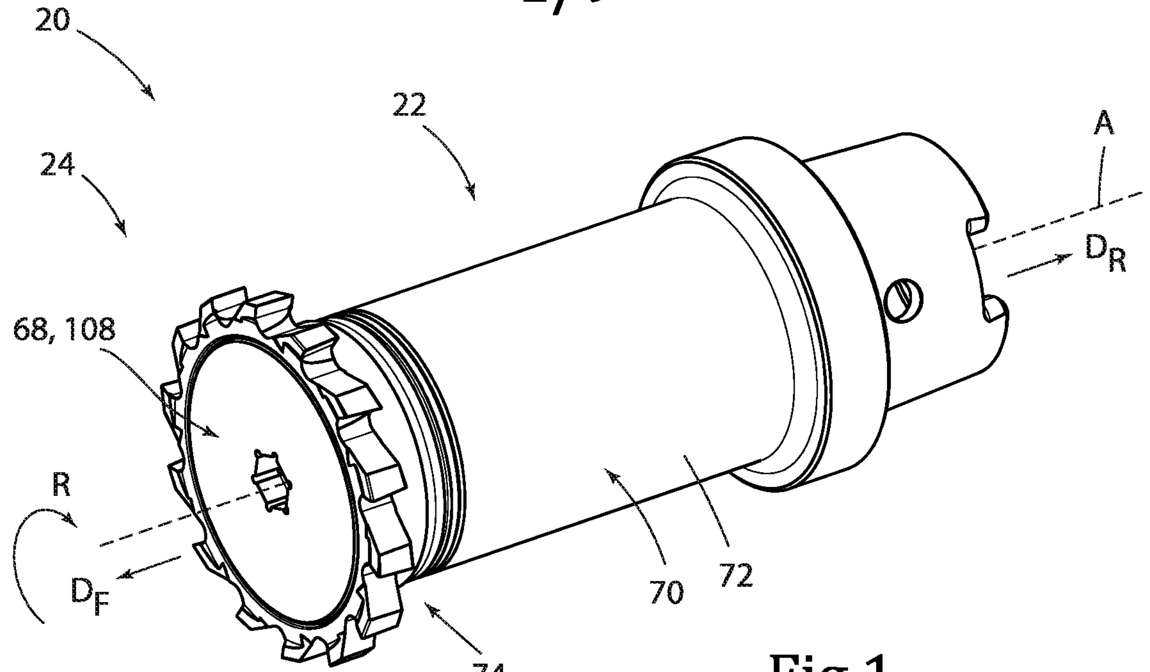
30. The rotary milling tool (20), according to any one of claims 27-29, wherein the fastening member (68) does not extend beyond the head forward plane (PF) in the forward direction (D_F).

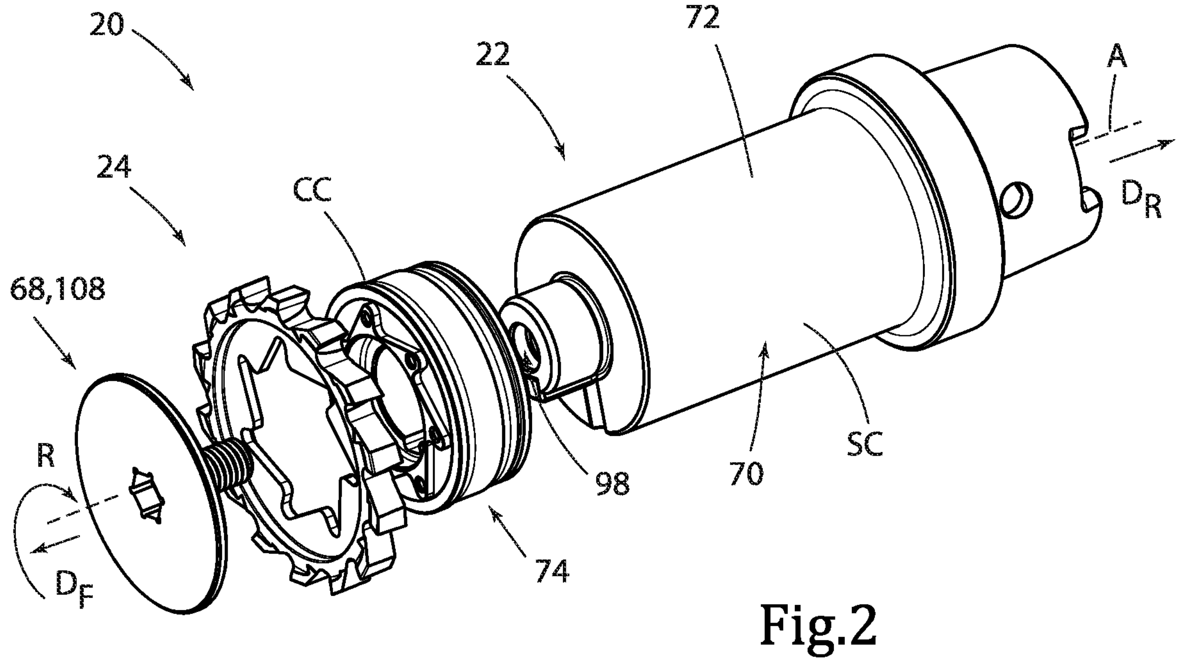
31. The rotary milling tool (20), according to any one of claims 27-30, wherein:

the external thread (104) comprises at least one unthreaded portion (106) extending from both ends of the external thread (104) so that the external thread (104) is non-continuous; and

the threaded bore (98) is a through bore having a bore rear inlet opening (98b);

the bore rear inlet opening (98b) is in fluid communication with the bore outlet opening (98a) via the at least one unthreaded portion (106).


20
22
24
A
D_R
68, 108
R
D_F
70
72
74
Fig.1


20
72
22
A
24
D_R
CC
68,108
R
D_F
98
70
SC
74
Fig.2

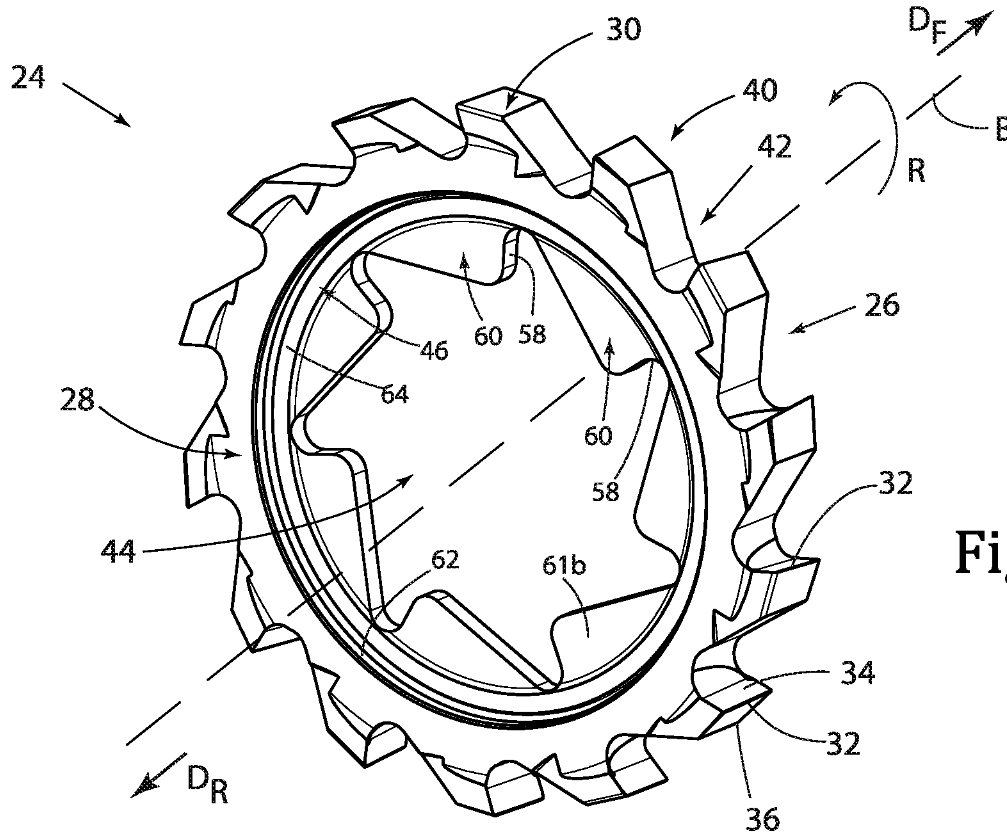
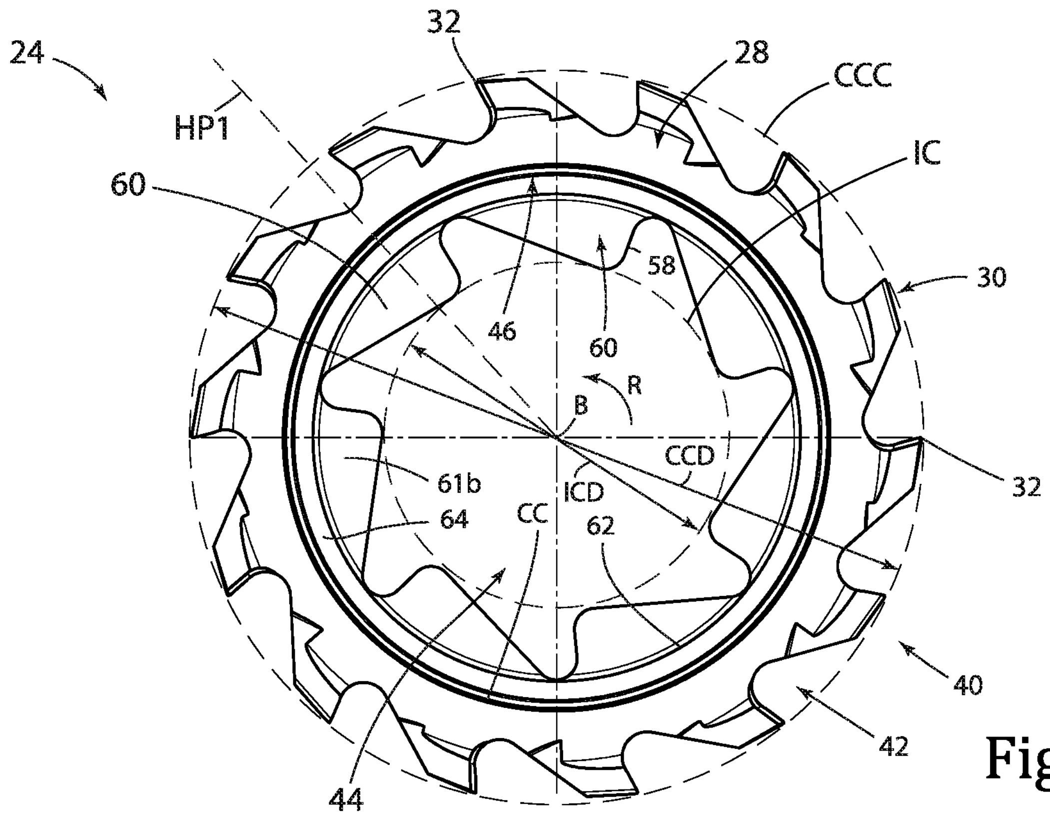

24
30
40
42
DF
B
R
26
28
46
60
58
64
60
58
32
44
62
61b
34
32
36
DR

Fig.3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32
28
CCC
HP1
IC
60
58
30
46
60
R
B
CCD
32
61b
ICD
64
CC
62
40
42
44

Fig.4

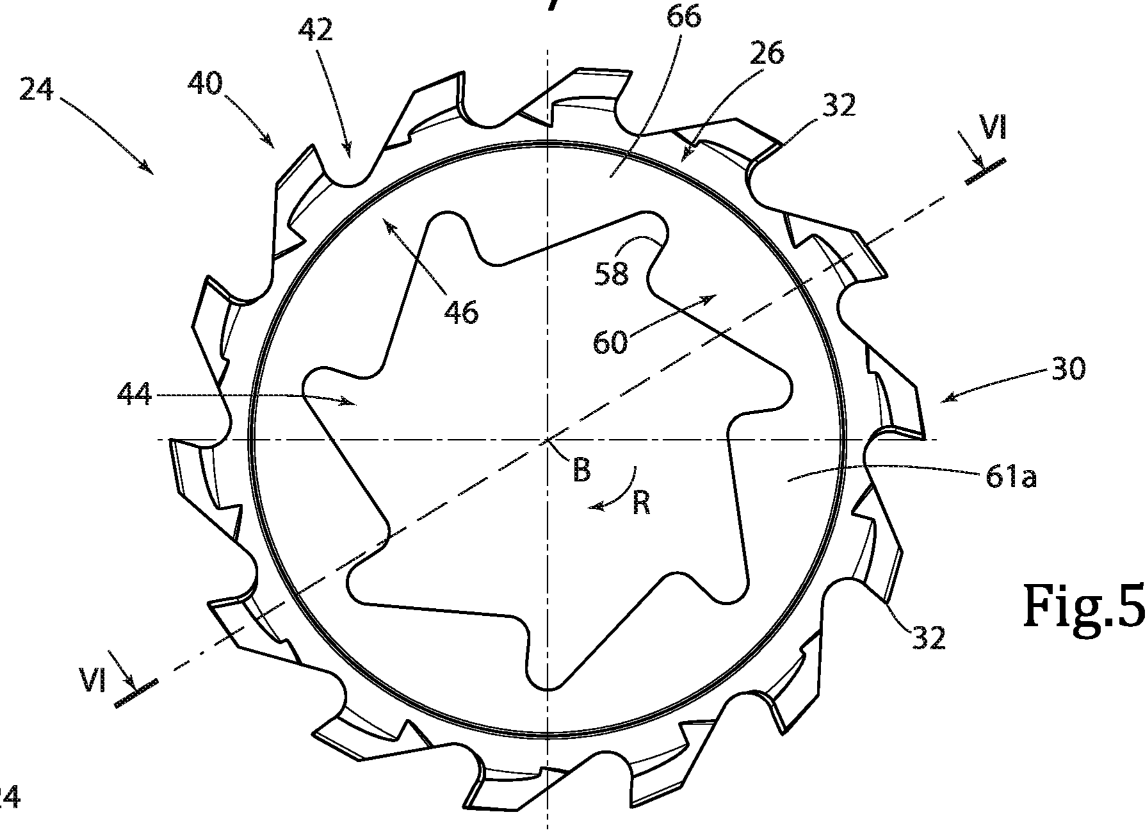

Fig.5

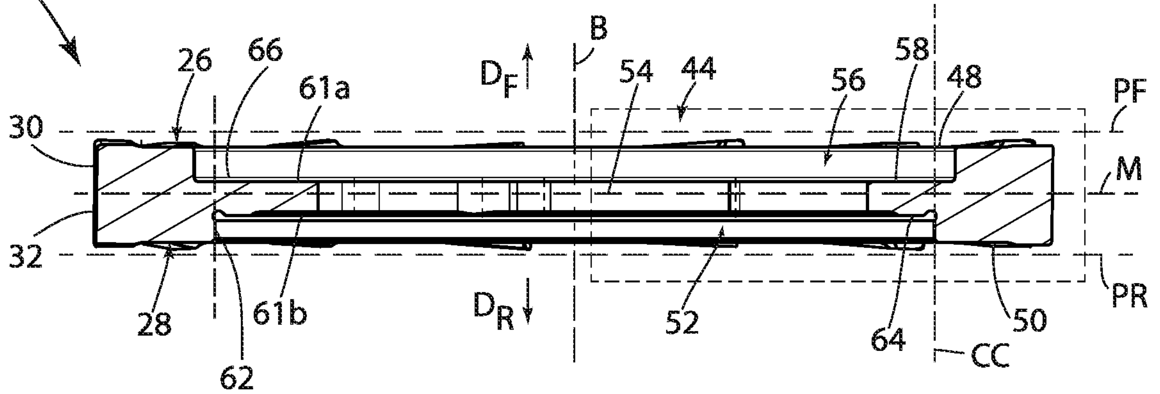

Fig.6

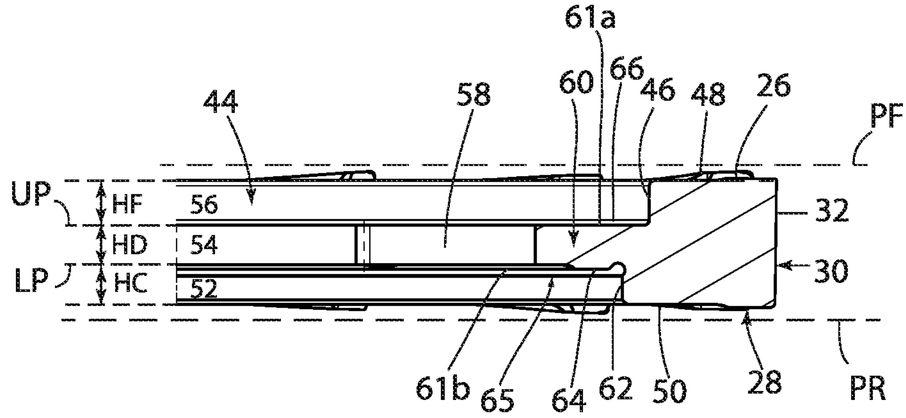

Fig.7

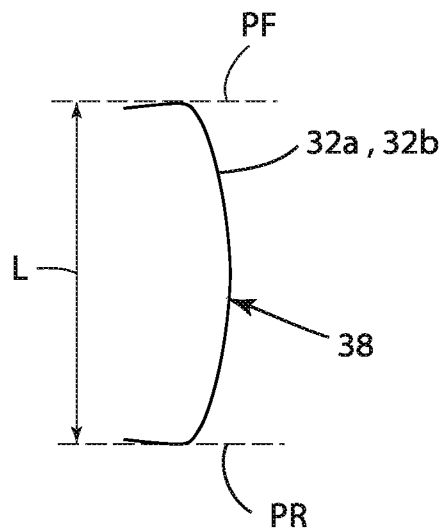

Fig. 8a

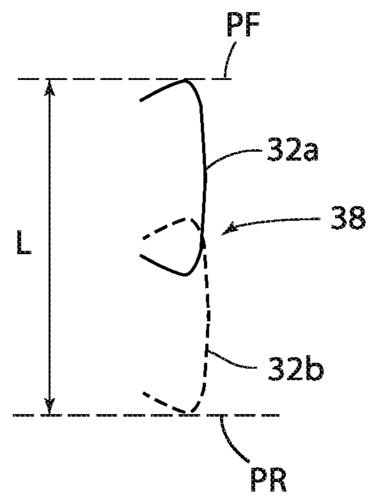

Fig. 8b

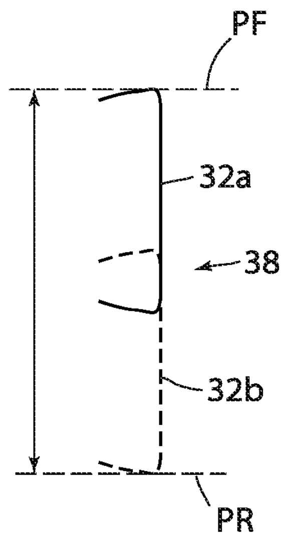

Fig. 8c

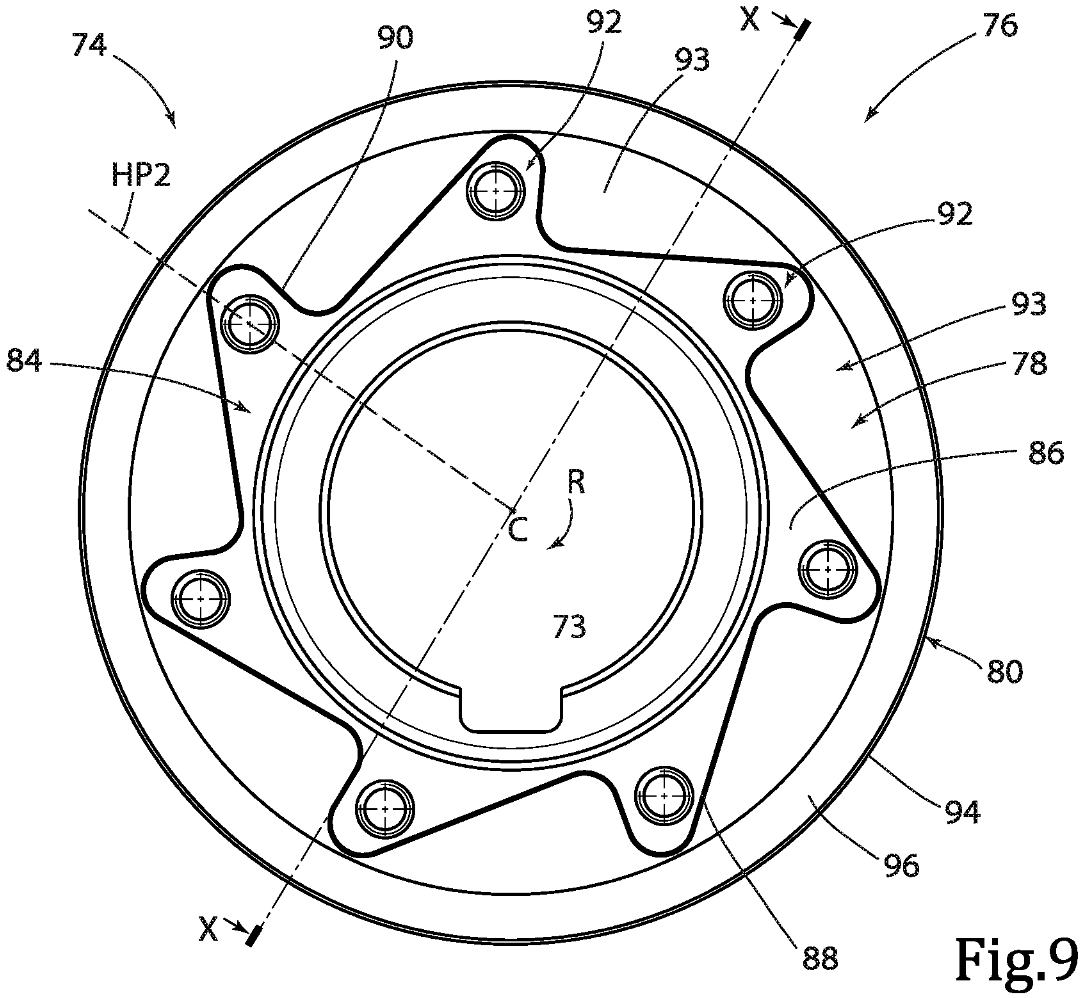
74
90
92
93
X
76
HP2
92
93
84
78
86
R
C
73
80
94
96
X
88

Fig.9

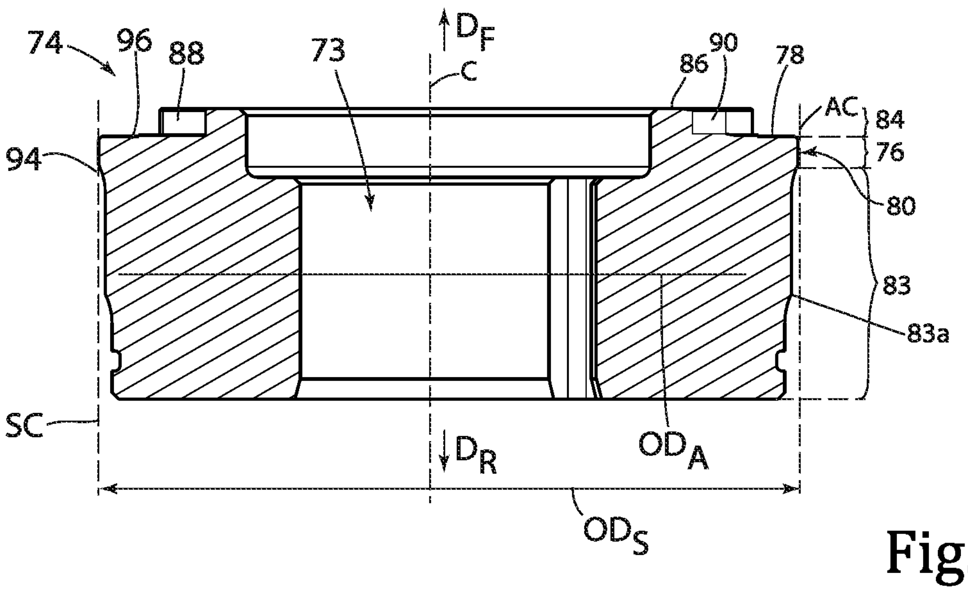
D_F
74
96
88
73
C
86
90
78
AC
84
76
94
80
83
83a
SC
D_R
OD_A
OD_S

Fig.10

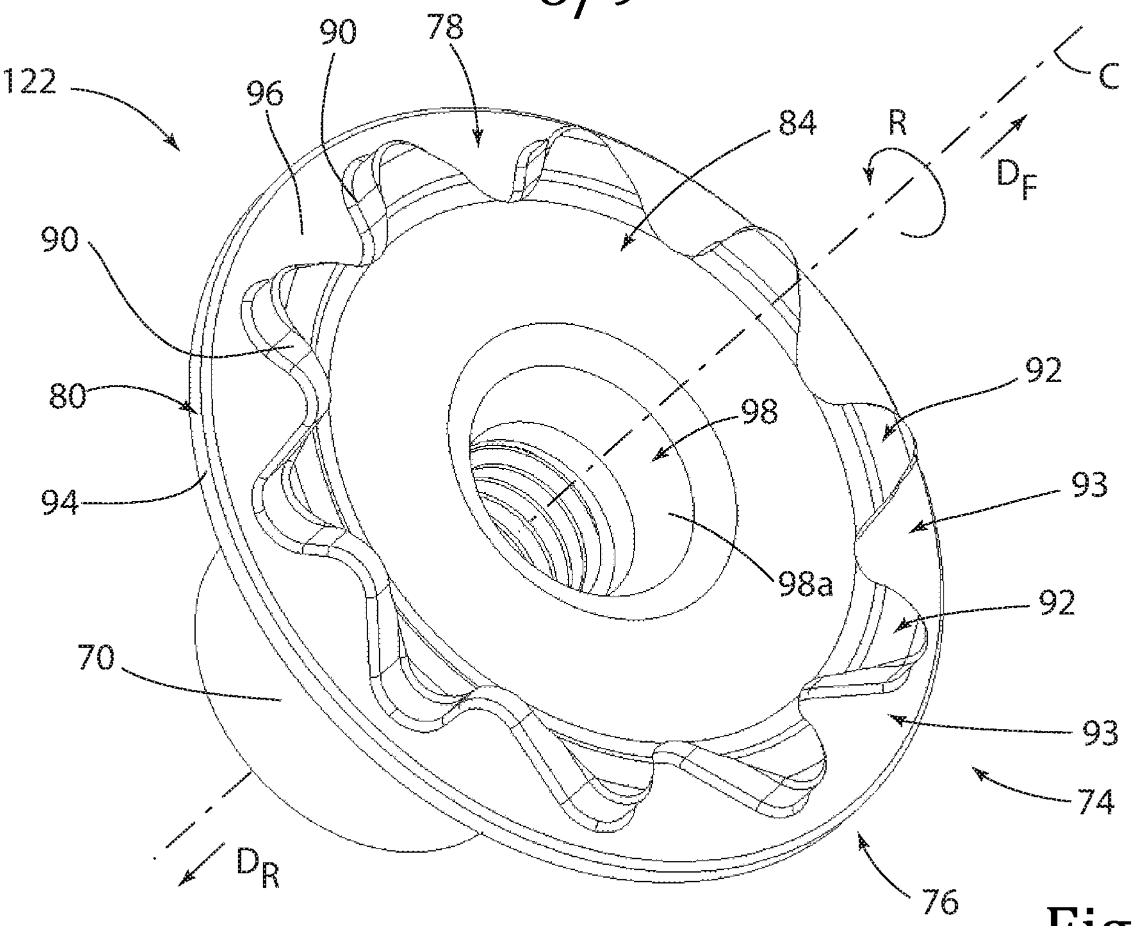
122
90
78
96
84
R
C
D_F
90
80
94
92
98
93
98a
92
70
93
74
D_R
76

Fig.11

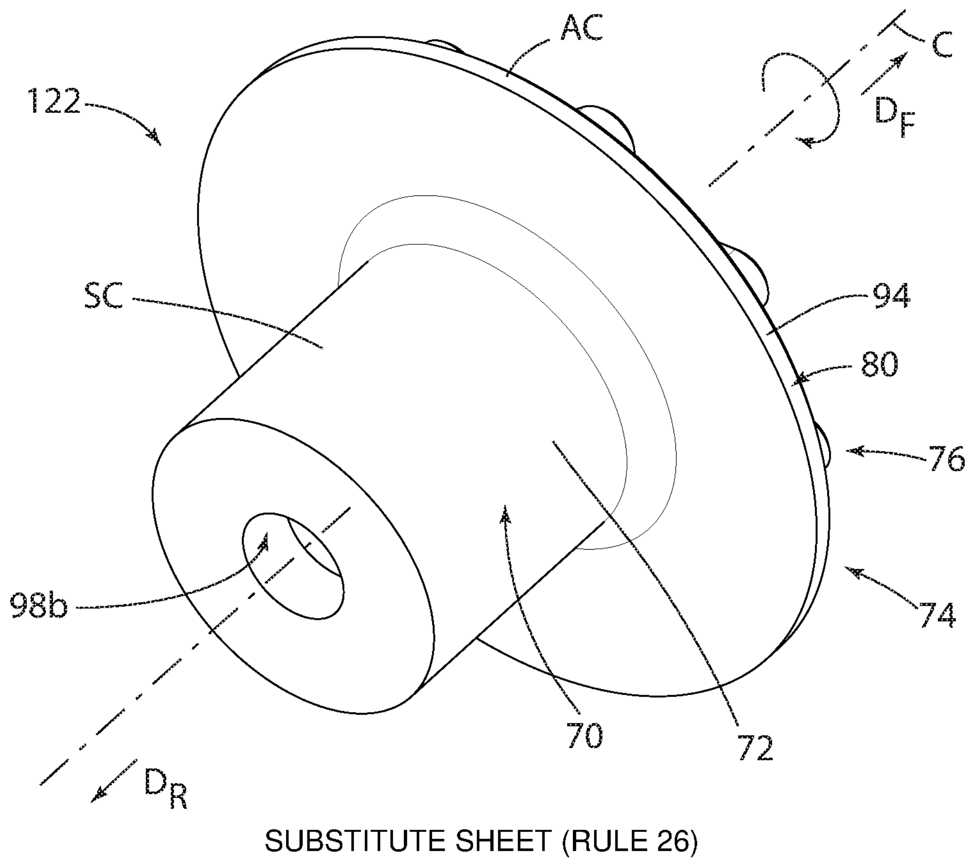
AC
C
122
D_F
SC
94
80
76
98b
74
70
72
D_R

Fig.12

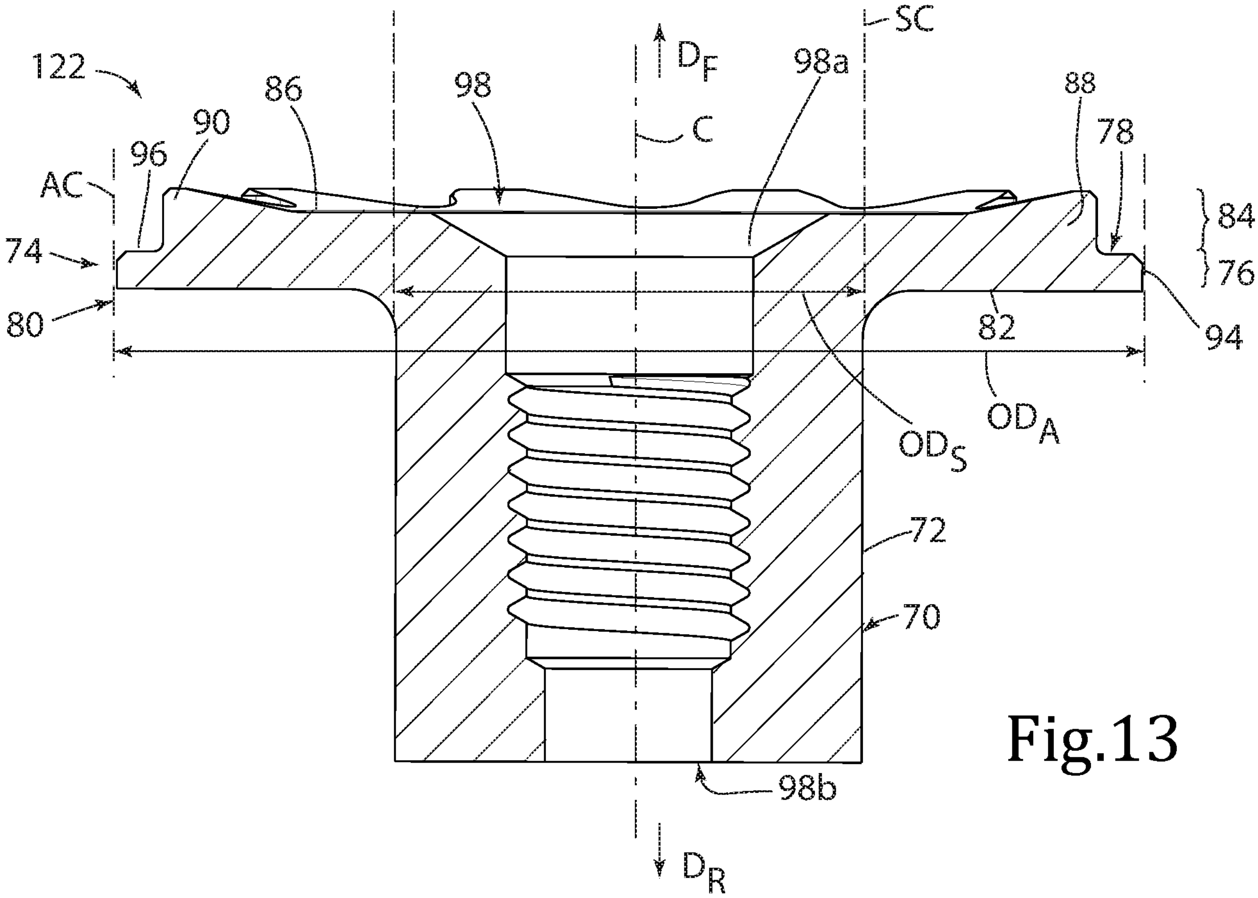
122
86
98
DF
98a
SC
88
78
C
90
96
AC
84
76
74
80
82
94
ODS
ODA
72
70
98b
DR

Fig.13

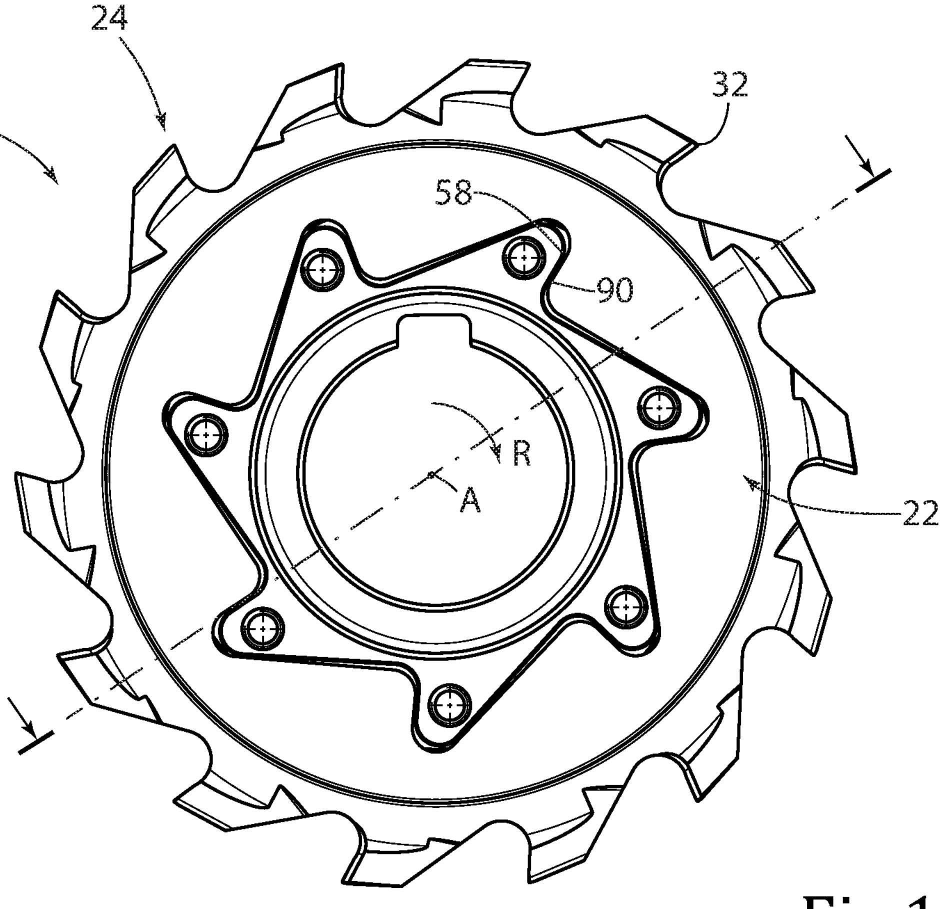
24
20
32
58
90
R
A
22

Fig.14

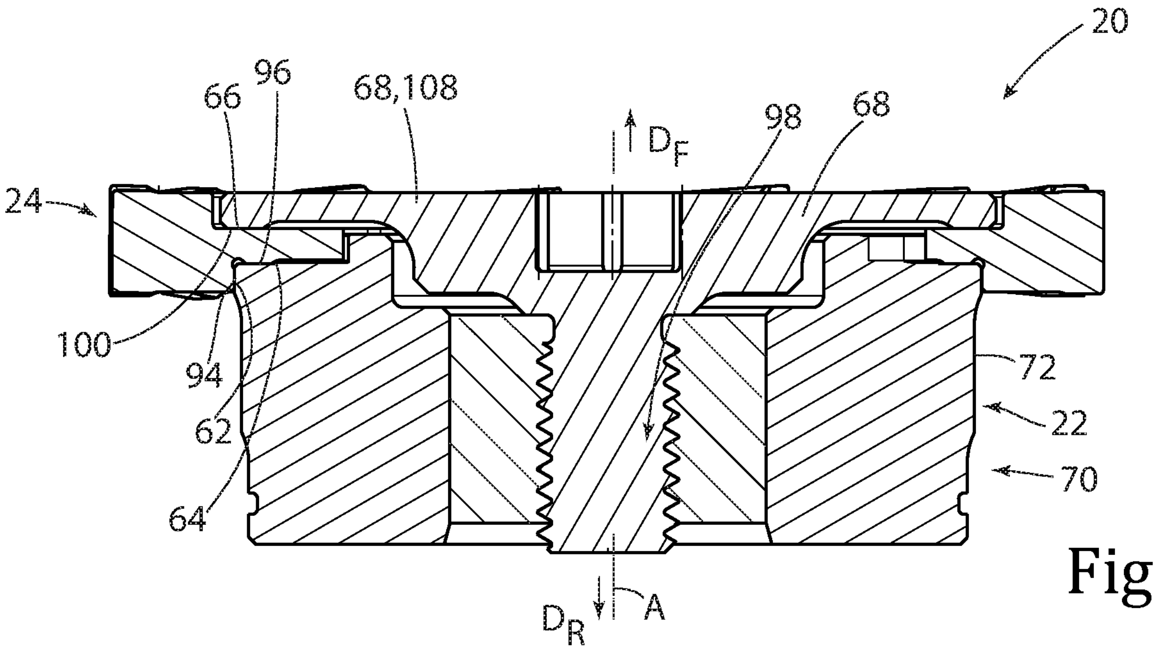
20
24
66
96
68,108
D_F
98
68
100
94
62
64
72
22
70
D_R
A

Fig.15

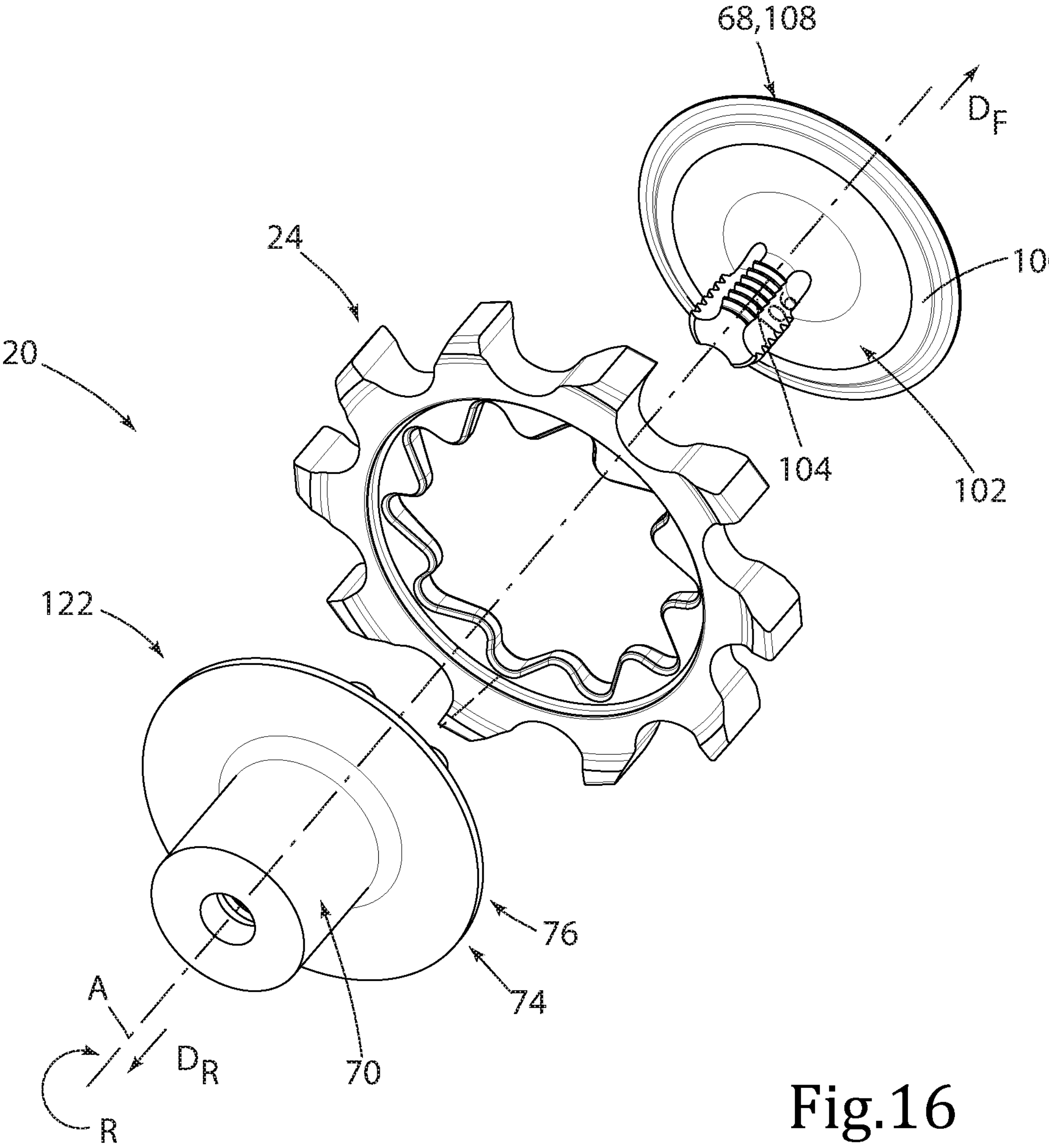
68,108
D_F
24
20
100
104
102
122
76
74
70
A
D_R
R

Fig.16

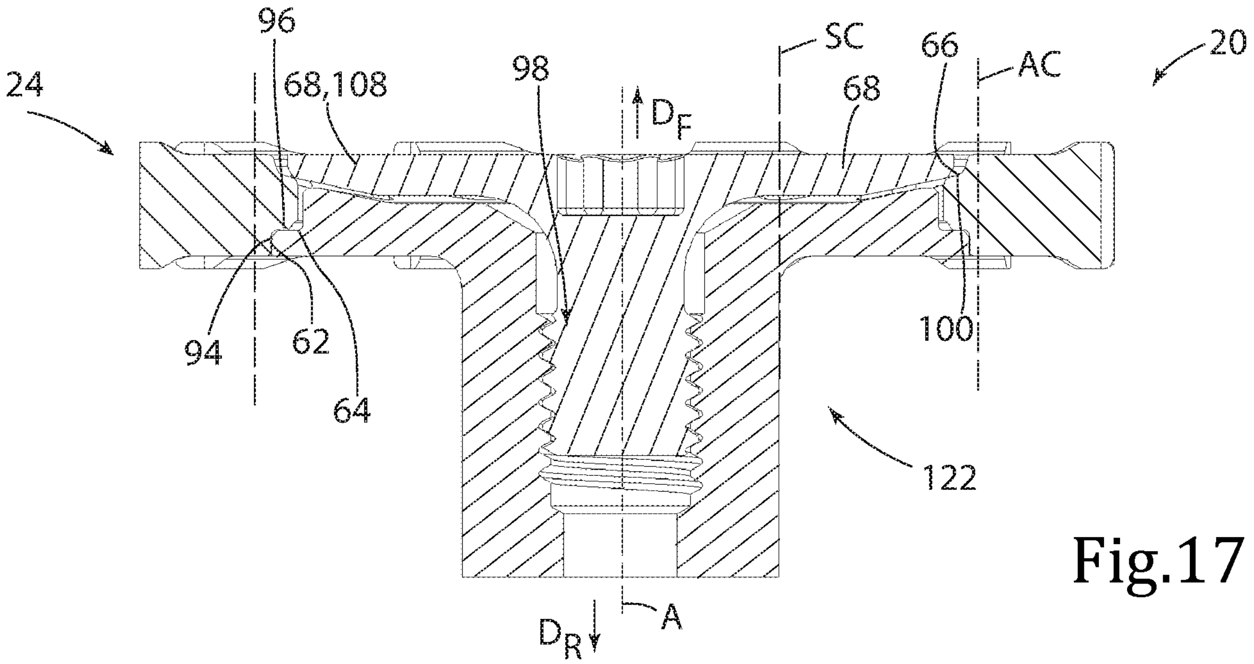
96
68,108
98
D_F
SC
66
68
AC
20
24
94
62
64
100
122
D_R
A

Fig.17

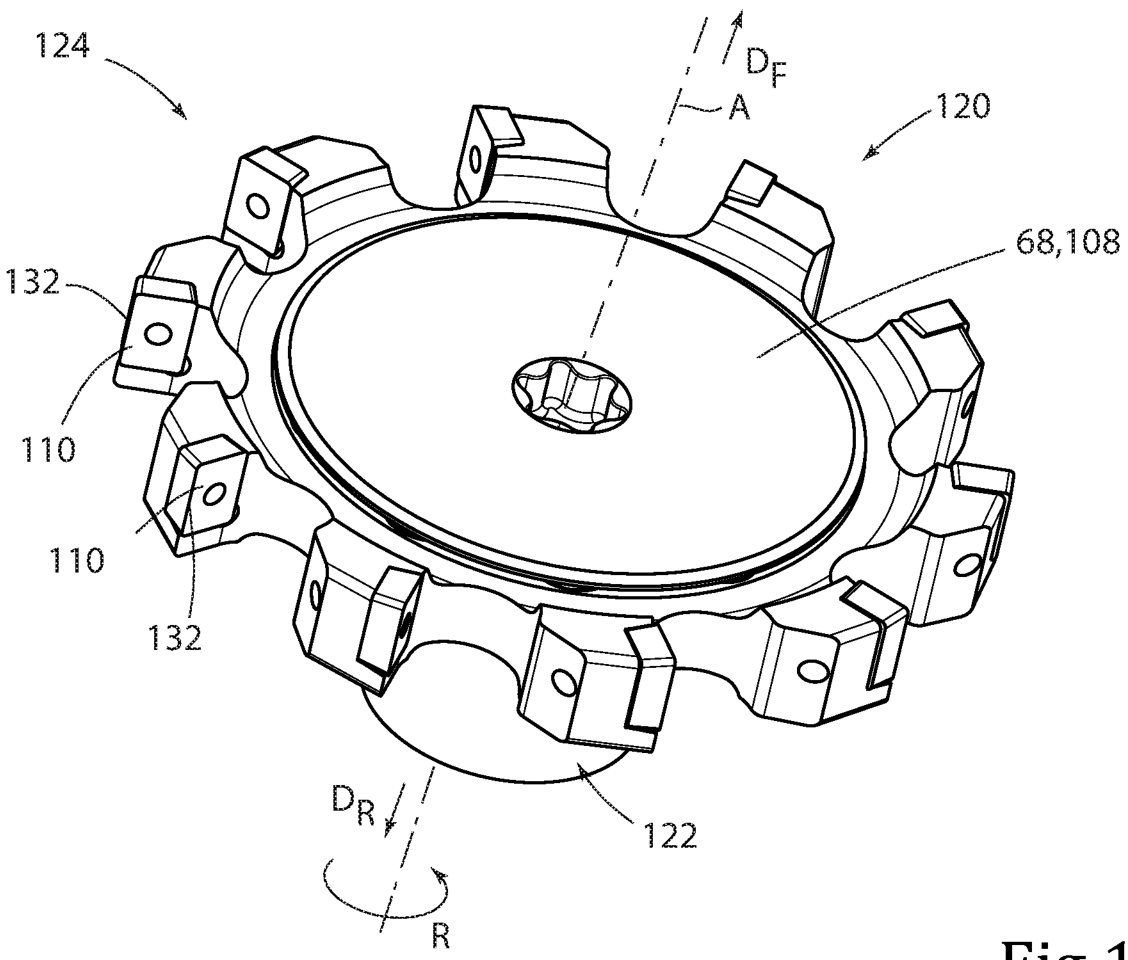
124
D_F
A
120
68,108
132
110
110
132
D_R
122
R

Fig.18

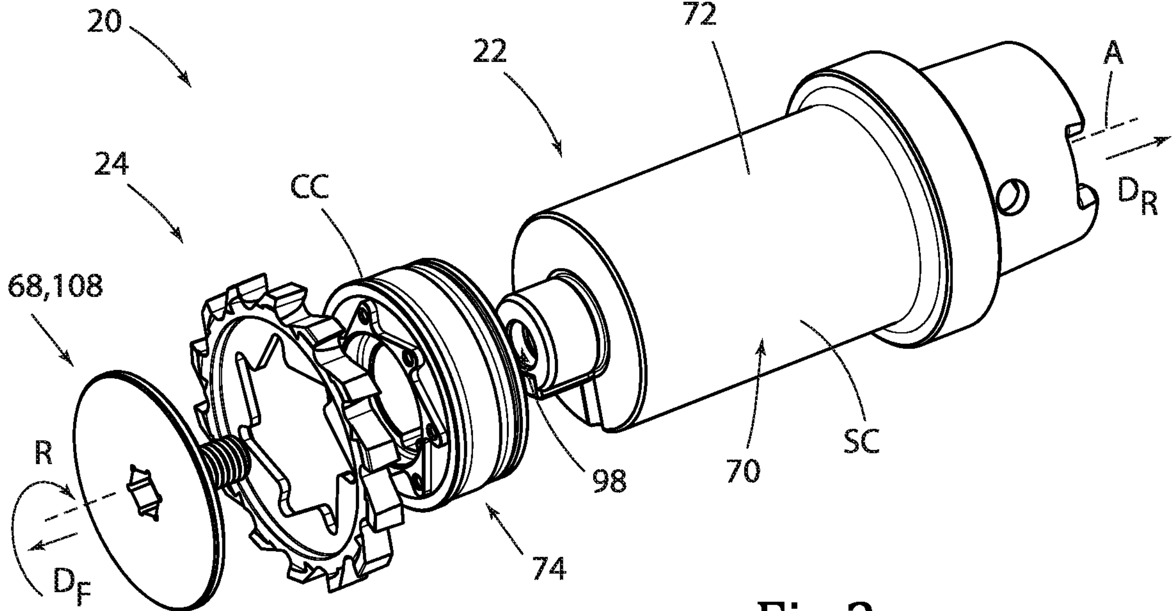

Fig.2