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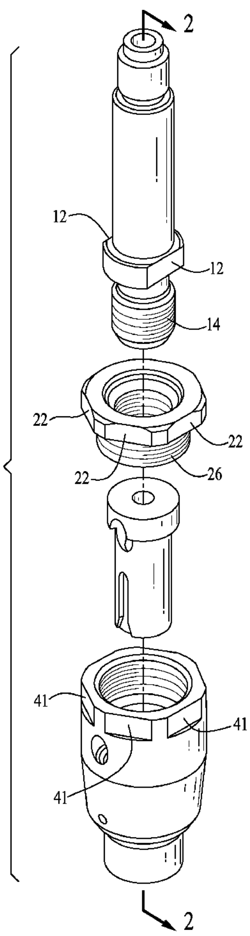
[Continued on next page]

(54) Title: INDEXABLE ABRASIVEJET CUTTING HEAD

Fig. 1



(57) Abstract: An abrasive cutting head assembly includes a generally annular gland between the cutting head and extension tube which has a first region of screw threads having a first lead that engages the threads of the extension tube, and a second region of screw threads having a second and different lead that engages the screw threads of the abrasivejet cutting head. By rotating the gland and cutting head with respect to the extension tube and by rotating the gland with respect to the cutting head, the position of the abrasive inlet hole in the cutting head body can be rotationally positioned as desired so that the abrasive feed tubing has an unobstructed path to the abrasive hopper while the risk of kinking is minimizing.

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TITLE: Indexable Abrasivejet Cutting Head

BACKGROUND OF THE INVENTION

The use of high velocity, abrasive-laden liquid jets to precisely cut a variety of materials is well known. Briefly, a high velocity liquid jet is first formed by compressing the liquid to an operating pressure of 3,500 to 150,000 psi, and forcing the compressed liquid (typically water) through an orifice having a diameter approximating that of a human hair; namely, 0.003 to 0.040 inches. The material defining the jet-forming orifice is typically a hard jewel such sapphire, ruby or diamond.

The resulting highly coherent waterjet is discharged from the orifice at a velocity which approaches or exceeds the speed of sound. The liquid most frequently used to from the jet is water, and the high velocity jet described hereinafter may accordingly be identified as a waterjet. Those skilled in the art will recognize, however, that numerous other liquids can be used without departing from the scope of the invention, and the recitation of the jet as comprising water should not be interpreted as a limitation.

To enhance the cutting power of the waterjet, abrasive materials have been added to the jet stream to produce an abrasive-laden waterjet, typically called an "abrasivejet". The abrasivejet is used to effectively cut a wide variety of materials from exceptionally hard materials (such as tool steel, aluminum, cast iron armor plate, certain ceramics and bullet-proof glass) to soft materials (such as lead). Typical abrasive materials include garnet, silica, and aluminum oxide having grit sizes of #36 through #200.

To produce the abrasivejet, the waterjet passes through a "mixing region" wherein a quantity of abrasive is entrained into the jet by the low pressure region that surrounds the flowing liquid in accordance with the Bernoulli Principle. The abrasive material, which is under atmospheric pressure in an external hopper, is drawn into the mixing region by the lower pressure region via a conduit (referred to as the “abrasive feed tube”) that communicates at one end with the interior of the hopper, and at the other end with the mixing region via an abrasive inlet hole formed in the cutting head housing that houses the jet-forming orifice jewel and mixing region.

The resulting abrasive-laden waterjet (or "abrasivejet") is then discharged against a workpiece through an abrasivejet nozzle that is supported closely adjacent the workpiece. The spent abrasive-laden water is drained away from the workpiece in any of a number of known ways, and collected in a collection tank for recycling of the abrasive and/or proper disposal.

Because the waterjet and abrasivejet are so destructive, wear of the jet-forming components is of particular concern. As the jet-forming orifice, mixing region and abrasivejet nozzle become worn, cutting efficiency decreases dramatically. The result is that the cutting process is dramatically slowed, and an excess of abrasive material is consumed in performing the cutting operation. Thus it is necessary to regularly change the jet-forming orifice, the mixing chamber and the abrasivejet nozzle. To maximize the life of the mixing region and abrasivejet nozzle, it is highly desirable to align them with the waterjet's axis. Because the fluid path thorough cutting head housing is several inches long, very minute alignment errors (e.g., a few tenths of a thousandths inch) are enough to cause premature failure of the abrasive jet nozzle. Accordingly, cutting heads are known which employ a removably inserted cartridge that contains the mixing region and the jet-forming orifice in accurate alignment, and which is securely held against movement within the housing in such a way that that the mixing region and jet-forming orifice are held in substantial alignment with the abrasivejet nozzle. An example of such a cartridge is illustrated and described in U.S. Patent 6,601,783.

In operation, it is frequently necessary to orient the abrasive inlet hole in the cutting head assembly so that the abrasive feed tubing has an unobstructed path to the abrasive hopper that does not interfere with the cutting process, and/or so that the risk of kinking the abrasive feed tubing is minimized. It is desirable to also minimize the length of abrasive feed tubing that must be used in order to provide a more fluid-dynamic path for the abrasive media to enter the waterjet stream and thereby increases the efficiency of abrasive material usage.

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SUMMARY

The invention permits the user of an abrasivejet cutting head to orient the abrasive inlet hole in the cutting head body so that the abrasive feed tubing has an unobstructed path to the abrasive hopper, while minimizing the risk of kinking the abrasive feed tube, which would negatively affect an abrasivejet cut on a work piece and interfere with efficient abrasive flow in the feed tube. Briefly, an abrasive cutting head assembly constructed in accordance with the invention includes a generally annular gland between the cutting head and the extension tube, and has a first region of screw threads with a first lead that engage the threads of the extension tube, and a second region of screw threads with a second lead that engage the screw threads of the abrasivejet cutting head. By rotating the gland and cutting head with respect to the extension tube and also rotating the gland with respect to the cutting head, the position of the abrasive inlet hole in the cutting head body can be rotationally positioned as desired. The ability to orient the cutting head also makes the cutting head more compatible with a wider range of mounting options across all OEM styles of abrasivejet systems, and permits retrofitting without a need to replace an existing extension tube, which may not be at the end of its service life, and/or other components upstream of the jet-forming orifice.

Additional details concerning the invention will be apparent to those of ordinary skill in the art from the following description of the preferred embodiment, of which the Drawing forms a part.

DESCRIPTION OF THE DRAWING

Figure 1 is an oblique front right elevation view, in perspective, of an abrasivejet cutting head assembly constructed in accordance with the invention;

Figure 2 is a right longitudinal sectional view, in schematic, of the assembled abrasivejet cutting head assembly shown in FIG. 1;

Figure 3 is an oblique front left elevation view, in perspective, of an abrasivejet cutting head assembly constructed in accordance with the invention and illustrating the manner by which the position of the abrasive inlet hole can be repositioned in accordance with the invention;

Figure 4 is a longitudinal sectional view of the cutting head assembly of Figure 4 in schematic;

Figure 5 is an oblique front left elevation view, in perspective, of an abrasivejet cutting head assembly constructed in accordance with the invention and illustrating the manner by which the position of the abrasive inlet hole can be repositioned in accordance with the invention;

Figure 6 is a longitudinal sectional view of the cutting head assembly of Figure 5 in schematic; and

Figures 7-8 are each an oblique front left elevation view, in perspective, of an abrasivejet cutting head assembly constructed in accordance with the invention and illustrating the manner by which the position of the abrasive inlet hole can be repositioned in accordance with the invention;

DESCRIPTION OF EMBODIEMENT

FIG. 1 is an oblique front right elevation view, in perspective, of an abrasivejet cutting head assembly constructed in accordance with the invention. FIG. 2 is a right longitudinal sectional view, in schematic, of the assembled abrasivejet cutting head assembly shown in FIG. 1. As illustrated in Figures 1 and 2, the preferred cutting head assembly is configured to interface with an extension tube 1, and comprises a gland 2, a cartridge 3, and a generally tubular housing body 4.

High pressure water entering the housing body 4 from the extension tube 1 passes through the jet-forming orifice 32 of a jewel orifice member 30 which is supported within the housing in axial alignment with an outlet passage 42 also formed within the housing. The outlet passage is sized to accommodate an abrasivejet nozzle (not shown) secured to the housing in axial alignment with the jet-forming orifice. An axially aligned fluid-conducting passage 34 is defined within the housing between the downstream end of the orifice and the upstream end of the outlet passage 42. An abrasive-conducting passageway 44 is formed within the housing to conduct abrasive material to the fluid-conducting passage 34 from an abrasive inlet hole 46 formed in the housing body 4. The abrasive-conducting passageway 44 intersects the fluid-conducting passage 34 at or adjacent to a mixing region 47 wherein the abrasive material becomes entrained into the waterjet emerging from the jet-forming orifice as a result of the low pressure region surrounding the jet. The body 4 further includes a plurality off engageable surface regions such as flats 41 circumferentially disposed about its generally upstream end region which can be gripped by a wrench or other tool to tighten or loosen the connection of the body 4 to the gland 2 as hereinafter described.

In the illustrated embodiment, the jet-forming orifice member 30, the mixing region 47 and the outlet passage 42, as well as a portion of the fluid-conducting passageway 34 and a portion of the abrasive-conducting passageway are formed in a replaceably insertable cartridge 3 which is securely held within the body 4 in accordance with the preferred configuration of the cutting head assembly. Those of ordinary skill in the art will recognize, however, that the mixing region, jet-forming orifice member and foregoing passageways need not be supported within, or formed in whole or in part as the case may be, by a cartridge. Abrasivejet cutting heads are known in the art, for example, which do not employ cartridges, and can be adapted in accordance with the teachings herein to provide the invention regardless the absence of a cartridge.

The extension tube 1 can be a standard part that many users in the industry already have, and is readily available. As is known in the art, the extension tube is simply a fitting at the downstream end of the high-pressure water supply line that interfaces with the cutting head to introduce high pressure water into the cutting head. The illustrated extension tube comprises an axially-extending, generally tubular body that is externally threaded, indicated at 14, at its downstream end region. The extension tube body further includes a plurality of engageable surface regions such as flats 12 that can be gripped by a wrench or other tool to tighten or loosen the extension tube connection to the abrasivejet cutting head. In the illustrated embodiment, the downstream end of the extension tube seals against the upstream face of the cartridge 3 in the region circumscribing the fluid passageway upstream of the jet-forming orifice 32.

The gland 2 interfaces with the extension tube 1, the body 4 and the cartridge (3), and acts as a carrier for the extension tube 1 to touch cartridge 4 on its top surface. The gland 2 has a generally annular cross section, a plurality of engageable surface regions on its exterior, such as flats 22, that can be gripped by a wrench or other tool to tighten or loosen the gland's connection to the abrasivejet cutting head and/or extension tube. At least a portion of the gland 2 is internally threaded, as at 24, to match and engage the external threads 14 of the extension tube 1. The gland 2 also has external threads 26 towards its downstream end region that match and engage internal threads 48 of the housing body 4. The illustrated gland is internally threaded at 24 because extension tubes are virtually always externally threaded, and the object is to be compatible with commonly available extension tubes. Those of ordinary skill in the art will recognize that external gland threads could replace the internal threads if the extension tube (or an interfacing adaptor) presents internal threads to the gland that must be coupled to. Likewise, the illustrated gland is externally threaded at 26 because the typical housing body is internally threaded. If, however, the gland must couple to external threads of a housing body (or adaptor), the internal threads can be utilized at 26. As described below, there is a difference in pitch between these two sets of threads 24, 26 of the gland.

As described earlier, the cartridge 3 carries the jewel 30 and its waterjet-forming orifice 32, and holds it within the cutting head body in alignment with the abrasive nozzle through which an abrasivejet exits the cutting head after abrasive material entering the cartridge via the abrasive inlet 44 becomes mixed with the waterjet stream.

In assembling the illustrated cutting head assembly, the cartridge 3 is placed into the body 4 and rests on a shoulder 41. The gland 2 is screwed into body 4 until its forward progress is restrained by contact with the body, and then gland 2 is backed off until its flats 22 line up with flats 41 of the body. These three components (i.e., the body 4, gland 2 and cartridge 3) are then screwed onto the downstream end of the extension tube 1 as a unit and secured. It may be noted that the extension tube may already be installed in the user's system

As gland 2 and body 4 are screwed together onto extension tube 1, the bottom surface of extension tube 1 contacts the top surface of cartridge 3. This results in the abrasive inlet 46 of body 4 being in its "home" orientation.

If it is desirable to change the angular position of the abrasive inlet about the axis 10, the user first loosens the gland 2 and body 4 together as a unit. Once loose, the user can then screw gland 2 out of body 4 slightly, and re-tighten them as a unit onto extension tube 1. This results in the abrasive inlet 46 of body 4 being in a different angular position with respect to the longitudinal axis 10 of the assembly. The cutting head assembly has now been "indexed" to the desired location.

To accomplish this, the external thread pitch of gland 2 is different than its internal thread pitch. If the pitches were the same, then any distance that gland 2 is moved away from body 4 in the axial direction will result in the same orientation of the abrasive inlet 46, and the same "landing spot" of extension tube 1 onto cartridge 3. For the reasons explained below, the currently preferred pitch ratio is 2:1, with the internal threads 24 of the gland having a pitch of 16 threads per inch, and the external threads 26 of the gland having a pitch of 8 threads per inch.

In determining the preferred difference in thread pitches, a number of factors are considered. For a particular outer diameter of gland 2, there is a finite range of thread pitches from which to choose. If the thread pitch is too coarse (i.e. less threads per inch), then gland 2 may not be "self-locking," wherein an axial load applied to the threads effectively keeps the parts from loosening themselves from each other owing to vibrations and cyclic pressure loads inherent in waterjet cutting.

If, on the other hand, the pitch of the external threads in gland 2 is too fine (i.e., more threads per inch), there is less surface area on each thread on which to distribute the axial load of extension tube 1 pushing against cartridge 3 as it is tightened. There would be less surface area due to machining standards dictating the shape of the thread as a function of its pitch, among other variables. Less surface area under the same load means more stress in the material (i.e., stress = pressure = force/area), increasing the susceptibility for fatigue failure.

Additionally, a thread with a finer pitch has less space between mating parts, which reduces the amount of space for anti-seize lubricant to pass freely. Without this space, the probability of stainless steel-to-stainless steel cold-welding is increased, an event called "galling" caused by adhesion between sliding surfaces. When a material galls, some of it is pulled with the contacting surface, especially if there is a large amount of force compressing the surfaces together. If galling occurs, both mating parts are damaged, perhaps beyond repair. Because the preferred gland is formed from stainless steel and, as is known in the waterjet cutting industry, the preferred material for the cutting head's body and the extension tube is stainless steel as well, avoidance of galling is a design consideration.

An additionally undesirable side-effect of a finer thread pitch is that the user would need to rotate the gland 2 many more times to remove it from body 4. This increases tool change-over time, and makes the product less user-friendly.

We have determined that the safety factor decreases by 41% when one compares the stresses experienced by an external thread pitch of 16 threads per inch (the pitch of a typical extension tube) with a pitch of 28 threads per inch (the maximum pitch currently believed allowable for the size of gland); in other words, the finer thread pitch of 28 threads per inch ("tpi") can take 41% less load than threads with a pitch of 16 tpi before yielding. The ratio of the finer pitch (i.e., 28) to the base of 16 tpi is 1.75:1.

Alternatively, and preferably, further calculations have shown that a pitch of 8 tpi will increase the safety factor of the thread load by 88%, using the same thread form of a 16 tpi thread. However, a thread form of a true 8 tpi external thread at the given diameter for gland 2 would be cut too deep to leave enough material to cut the internal threads 24. To obtain the fatigue resistance advantage of the courser thread and achieve a pitch differential ratio greater than the maximum pitch of 28 tpi, the external threads of gland 2 must be courser than the 16 tpi base pitch of extension tube 1. But it is undesirable to use a single 8 tpi thread with a 16 tpi thread form, due to an overall poor appearance and fatigue issues that arise from a single 8 tpi thread engaging a 16 tpi thread form (which is not cut as deep as a true 8tpi form and thereby results in half of the contact area between the gland and the body, and an increase the load each thread must take, compared with the inter-engaging of an 8 tpi thread with an 8 tpi thread form or a 16 tpi thread with a 16 tpi thread form.

Accordingly, the use of a “two-start” thread (also referred to as “two-lead” or “dual-lead” thread) is preferred in that event. A two-start thread consists of two separately machined, parallel threads wrapped around the relevant threaded portion of the gland’s body, and wherein the machining of the thread’s “starts” (also referred to as “leads”) is 180 degrees apart. For example, a 16 tpi two-start thread would have the appearance of a 16 tpi thread; however the mating parts would move like an 8 tpi thread. This allows for the mating parts to move along the longitudinal axis twice as far with the same number of rotations. The linear distance the gland travels per revolution is called the “lead” of the thread, while the “pitch” of a thread is the distance from one crest of a thread to its next crest. Metric-based threads are typically defined by their pitch, while inch-based threads are typically defined by their “threads per inch, or “tpi”, which is the reciprocal of the pitch. Thus a thread with 16 tpi has a pitch of $1/16^{th}$ inch. A larger “tpi” accordingly denotes a smaller pitch.

Consequently, the preferred 16 tpi, two-lead thread decreases the total number of rotations the user needs to remove the gland 2 from the body 4 to replace cartridge 3, and appears to have full 360 degree indexability as intended by the design. The selected two-start, 8 tpi thread is compatible with the typical 16 tpi internal thread found within conventional cutting head assembly bodies that conventionally engage the external 16 tpi thread at the downstream end of the extension tube, making the preferred gland compatible for use with existing OEM systems that their owners wish to modify in order to re-position the abrasive inlet. At the same time, the 8tpi “two-start” thread is 41% stronger than the 28 tpi thread, and has a pitch differential of 2:1 as opposed to the 28 tpi’s 1.75:1. Thus, the 16 tpi, two-lead thread is preferred; however, those of ordinary skill in the art will recognize that the lead of the gland’s external threads may be any integral multiple of its pitch without departing from the scope of the invention. Broadly, "lead" is equal to N x "pitch", where N is a non-zero integral representing the number of starts.

In discussing preferred thread pitches and thread leads above, the U.S. Standard units has been utilized because this is an industry standard in the U.S. that is recognized internationally as such. It may be noted that 16tpi converts mathematically to 1.588 mm/thread; however the closest standard ISO metric thread pitch is 1.5 mm/thread. Similarly, 8 tpi converts mathematically to 3.175mm/thread, with the closest ISO metric standard being 3mm/thread. This information pertaining to metric equivalence of the preferred thread characteristics is incorporated by reference into the foregoing description as the metric equivalent where U.S. units are used as a convenient alternative to the appearance of such information adjacent each U.S. unit.

Users of the novel assembly described herein can orient the abrasive inlet of the cutting head assembly to any required direction. This ability minimizes the risk of kinking the abrasive feed tube, which can negatively affect the efficiency and quality of an abrasivejet cut on a work piece, allows the end user to use less abrasive feed tubing, and provides a more advantageous fluid-dynamic path for the abrasive media to enter the waterjet stream, increasing the efficiency of abrasive media usage. The ability to orient the cutting head also makes the cutting head more compatible with a wider range of mounting options across all OEM styles of waterjet machines without using entirely new parts above the cutting head in a user's waterjet system.

Figures 3-9 illustrate the method by which Users of the novel assembly described herein can orient the abrasive inlet of the cutting head assembly to any required direction. The hex flats of the gland 2 and body 4 are aligned in the "home" position described earlier, with representative flat "A" of gland 2 and flat "B" of body 4 being marked for visual clarity so that the reader can note their positions on each of the Figures as the method is described. As illustrated in Figure 4, the extension tube 1 is within the gland 2, and has contacted the cartridge 3 in the home position, and perhaps backed off a bit to align the flats "A", "B" as described earlier.

The body 4 and gland 2 are then loosened as a unit, rotating the flats “A”, “B” clockwise in general continued alignment, as illustrated in Figure 5. It can be noted that the abrasive inlet 46 has now rotated about axis 10 (Figure 2) from its slightly right oblique position illustrated in Figure 3 to a left oblique position in Figure 5. The extension tube 1 has now been longitudinally spaced from the cartridge 3, as illustrated in Figure 6.

As next illustrated in Figure 7, the gland 2 is next rotated counterclockwise, and moves away from the body 4 and towards the extension tube 1, thereby increasing the longitudinal distance between gland and body. As illustrated in Figure 8, the body 4 and gland 2 are then tightened as a unit onto the extension tube 1. The space between the gland 2 and body 4 is retained. As illustrated in Figure 8, the abrasive inlet 46 is now in a different position is spaced from the home position of Figure 3 at this point.

The foregoing steps can then be repeated as desired and appropriate to obtain the desired position for the abrasive inlet 46, whose repositioning is a result of the lead differential provided by the gland 2 when rotated relative to the body 4 (Fig. 7) so that the angle of the gland’s rotation relative to the body is different than the angle of rotation that loosens and/or tightens the body/gland unit from/to the extension tube 1.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention, which is defined by the appended claims.

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What is claimed is:

1. An abrasive jet cutting head assembly of the type selectively tightened onto and untightened from the extension tube of an abrasivejet cutting system, and comprising:

a cutting head body having upstream and downstream ends, an internal axially-extending passageway in fluid communication with both said ends, and an abrasive inlet opening in fluid communication with said internal passageway, the cutting head body being threaded at its upstream end region with threads of a first pitch and first lead;

a gland of generally annular cross-section having upstream and downstream ends, the downstream end region of the gland being threaded to engage the threads of the cutting head body to enable the gland to be selectively tightened to and untightened away from the cutting head body, the gland being further threaded at its upstream end region with threads having a lead different than the threads at its downstream end region and configured to couple to the discharge end of an extension tube that supplies water to the internal passageway of the cutting head body,

the gland positioned between the cutting head body and the extension tube in such a way that water from the discharge end of the extension tube enters the cutting head body.

2. The abrasivejet cutting head assembly of Claim 1 wherein the threads at the upstream end region of the gland are external threads.

3. The abrasivejet cutting head assembly of Claim 1 wherein the threads at the downstream end region of the gland are internal threads.

4. The abrasivejet cutting head assembly of Claim 1 wherein the ratio of the thread lead at the upstream end of the gland the thread lead at the downstream end region of the gland is in the range of approximately 1.75:1 to 2:1, inclusive.

5. The abrasive cutting head assembly of Claim 1 wherein the threads at the downstream end region of the gland are multi-start threads.

6. The abrasive cutting head assembly of Claim 1 wherein the threads at the downstream end region of the gland are 2-start threads.

7. The abrasivejet cutting head assembly of Claim 6 wherein the pitch of the two-start threads results in approximately 16 threads per inch with a lead of approximately 1/8-inch.

8. The abrasivejet cutting head assembly of Claim 6 wherein the pitch of the threads at the upstream end region of the gland results in approximately 16 threads per inch.

9. The abrasivejet cutting head assembly of Claim 1 wherein the pitch of the threads at the upstream end region of the gland results in approximately 16 threads per inch.

10. The abrasivejet cutting head assembly of Claim 9 wherein the pitch of the threads at the downstream region of the gland results in approximately 16 threads per inch.

11. The abrasivejet cutting assembly of Claim 1 wherein the a cutting head body includes a plurality of engageable surface regions on its exterior that can be gripped by a tool to aid in tightening and untightening the cutting head body with respect to the extension tube.

12. The abrasivejet cutting assembly of Claim 11 wherein the gland includes a plurality of engageable surface regions on its exterior that can be gripped by a tool to aid in tightening and untightening the gland with respect to the extension tube.

13. The abrasivejet cutting assembly of Claim 12 wherein at least some of the engagable surface regions of the gland are positionable with respect to at least some of the engagable surface regions of the cutting head body so as to be simultaneously grippable in such a way that the cutting head body and gland can be rotationally tightened onto and loosened from the extension tube as a unit.

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14. For use with an abrasive jet cutting system of the type including

an extension tube having a threaded downstream end region adjacent a discharge end for delivering water to an abrasivejet cutting head secured to said threaded downstream region, and

an abrasivejet cutting head having a body with upstream and downstream ends, an internal axially-extending passageway in fluid communication with both said ends, and an abrasive inlet opening in fluid communication with said internal passageway, the cutting head body being threaded at its upstream end region with threads of a first pitch to engage the threaded downstream end region of the extension tube to sealingly secure the abrasivejet cutting head to the discharge end of the extension tube so that said water passes through the cutting head body within said internal passageway;

a gland of generally annular cross-section comprising upstream and downstream end regions, the downstream end region of the gland being threaded to engage the threaded upstream end region of the cutting head body with threads having a first pitch and a first lead to enable the gland to be selectively tightened to and loosened from the cutting head body, the gland being further threaded at its upstream end region with threads having a lead different than the threads at its downstream end region to engage the threaded downstream region of the extension tube so that said water from the discharge end of the extension tube passes into said internal passageway of the cutting head body.

15. The gland of Claim 14 wherein the thread pitch at the downstream end region of the gland results in approximately 16 tpi.

16. The gland of Claim 15 wherein the downstream end region of the gland has a two-start threaded region.

17. The gland of Claim 15 wherein the threads at the downstream end region of the gland are external threads.

18. The gland of Claim 15 wherein the thread pitch at the upstream end region of the gland results in approximately 16 tpi.

19. The gland of Claim 18 wherein the threads at the upstream end region of the gland are internal threads.

20. A method for positioning the abrasive inlet of an abrasivejet cutting head of an abrasivejet cutting system of the type typically including

an extension tube having a threaded region adjacent its discharge end for delivering water to an abrasivejet cutting head secured to said discharge end, and

an abrasivejet cutting head disposed between upstream and downstream ends about a longitudinally-extending axis, and having an internal axially-extending passageway in fluid communication with both said ends, and an abrasive inlet opening in fluid communication with said internal passageway, the cutting head body being threaded adjacent its upstream end with threads of a first pitch to engage said threaded region of the extension tube to sealingly secure the abrasivejet cutting head to the discharge end of the extension tube so that said water passes through the cutting head body within said internal passageway,

said method comprising the steps of:

screwing a generally annular gland to said threaded region of the extension tube utilizing threads of the annular gland that have a first lead and a first pitch that is compatible with the threaded region of the extension tube;

screwing the upstream end of the cutting head to the gland utilizing threads of the gland that have a second lead that is different than the first lead, and a pitch that is compatible with the threads of the cutting head; and

adjusting the relative rotational positions of the gland and the cutting head to position the abrasive inlet at a desired position about the longitudinal axis with the cutting head sealingly coupled to the extension tube so that said water discharged from the extension tube passes through the cutting head body within said internal passageway.

21. The method of Claim 20 wherein the gland is first tightened to the cutting head, and the gland and cutting head are then tightened to the extension tube substantially as a unit.

22. The method of Claim 21 wherein relative positions of the gland and cutting head are adjusted by loosening the gland and cutting head from the extension tube substantially as a unit, thereafter loosening the gland from the cutting head, and thereafter re-tightening

the gland and cutting head substantially as a unit onto extension tube to position the abrasive inlet of the body at a desired angular position with respect to the longitudinal axis.

23. A method for adding a positional adjustment capability for the abrasive inlet of an abrasive cutting head threadably coupled to an extension tube comprising the step of providing a generally annular gland for positioning between the cutting head and extension tube having internal threads with a first lead to engage external threads of the extension tube, and having external threads with a second lead to engage internal threads of the abrasivejet cutting head, the first and second leads being unequal.

24. The method of Claim 23 including the step of providing a ratio of first and second leads that is substantially in the range of 1.75:1 to 2.0:1.

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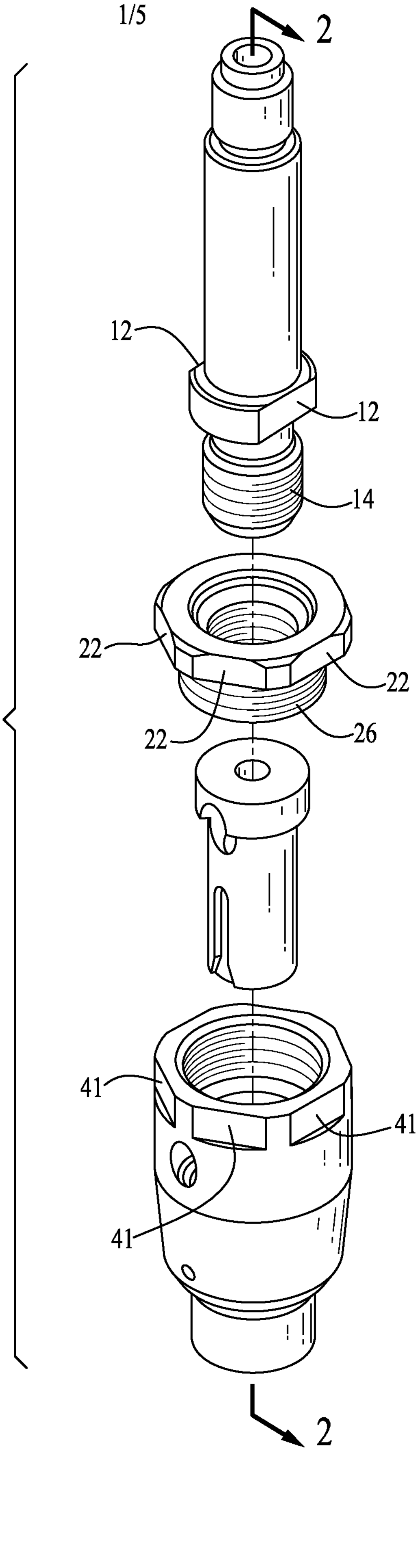

FIG. 1

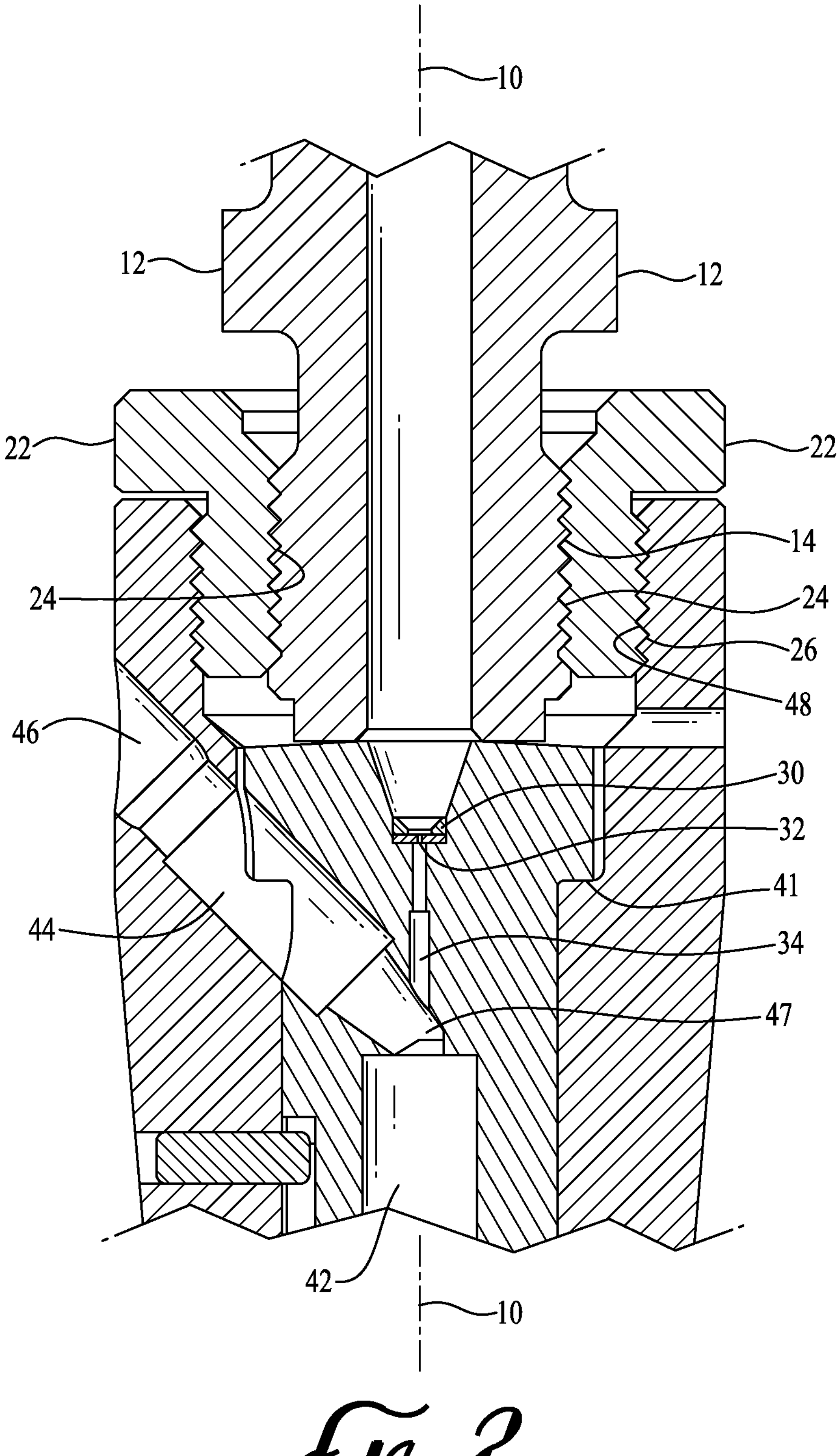

FIG. 2

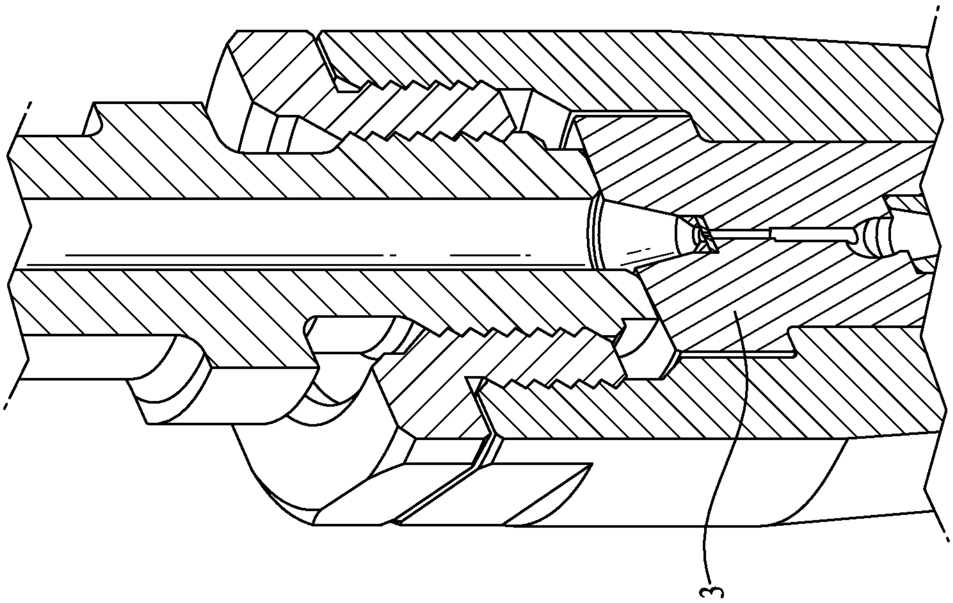

FIG. 4

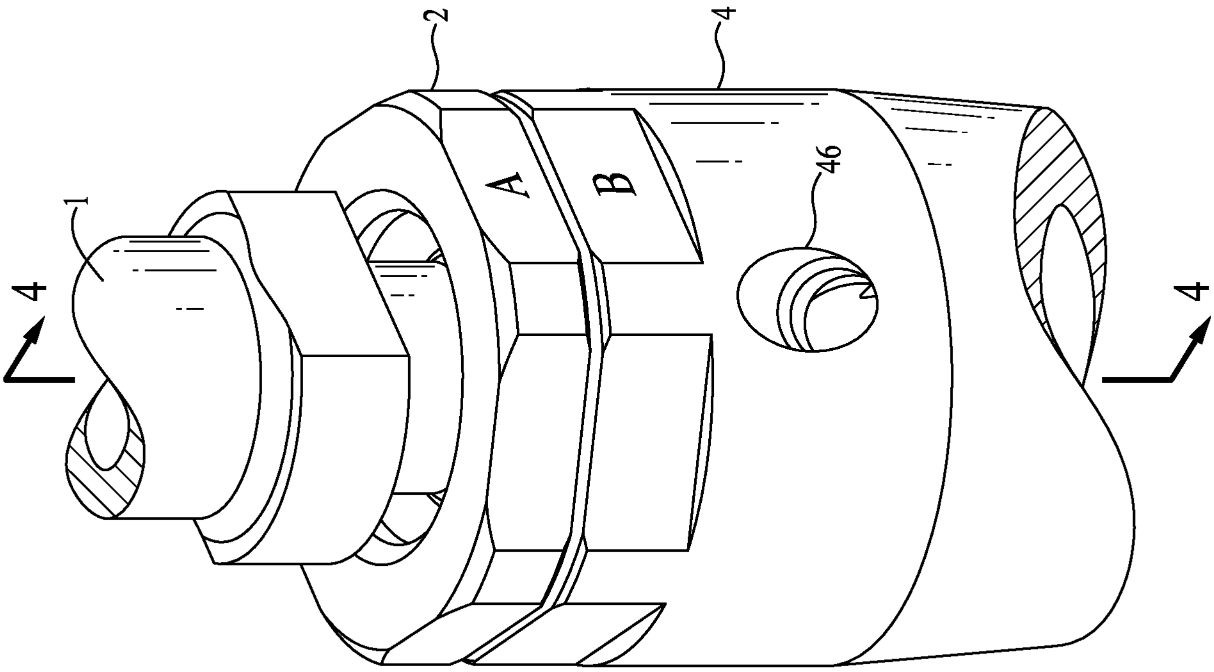

FIG. 3

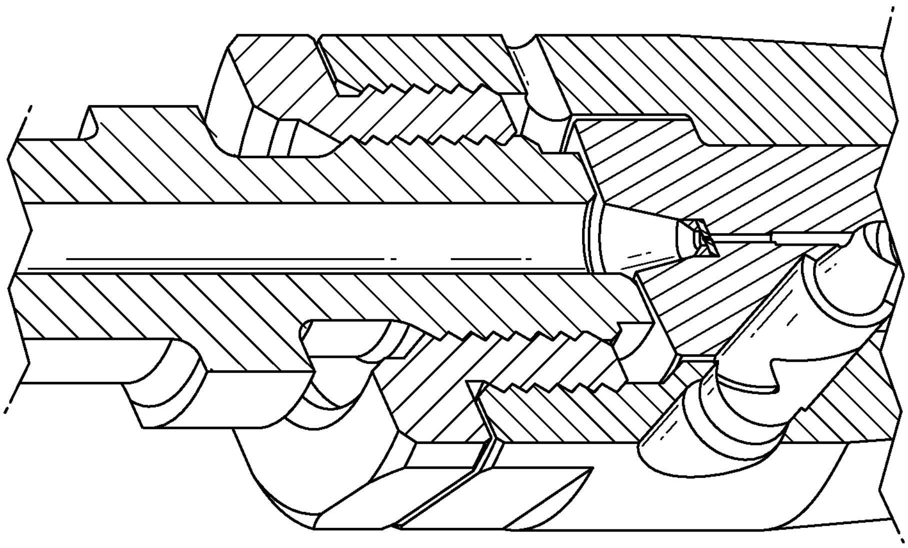

Fig. 6

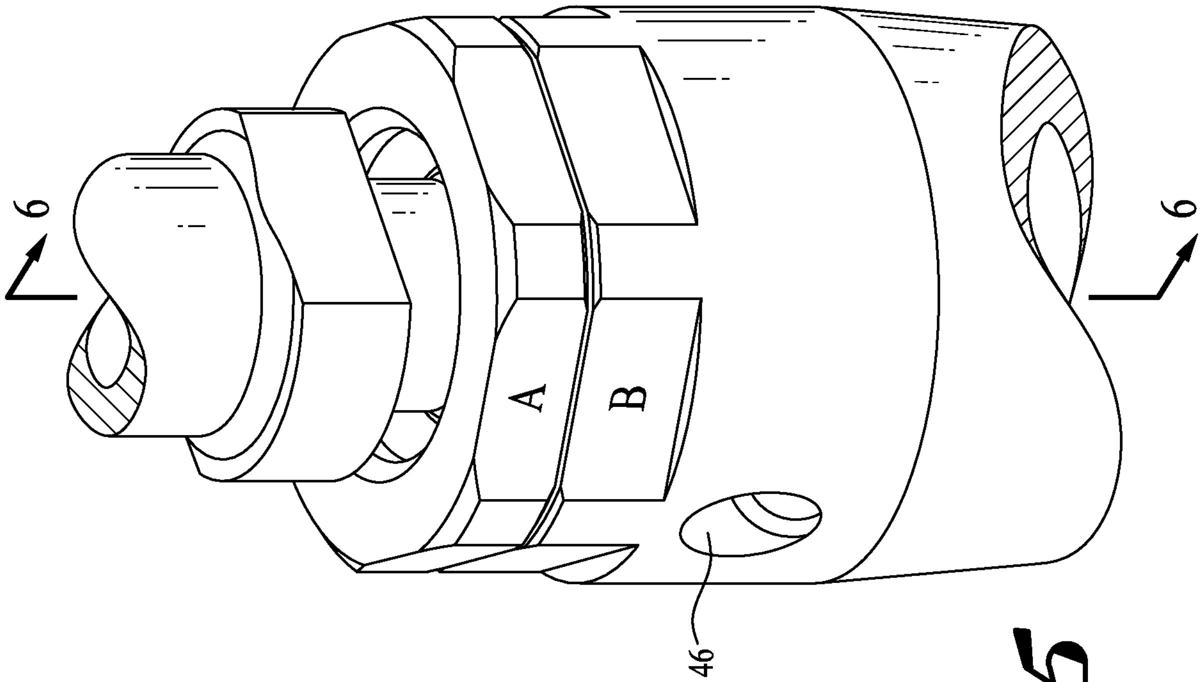

Fig. 5

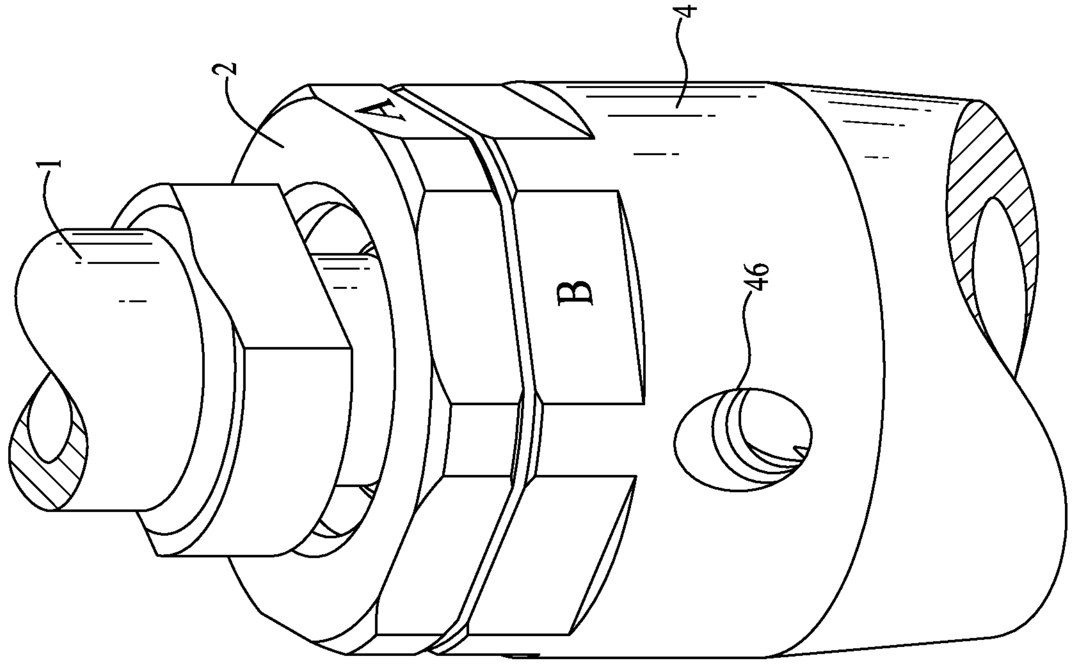

Fig. 8

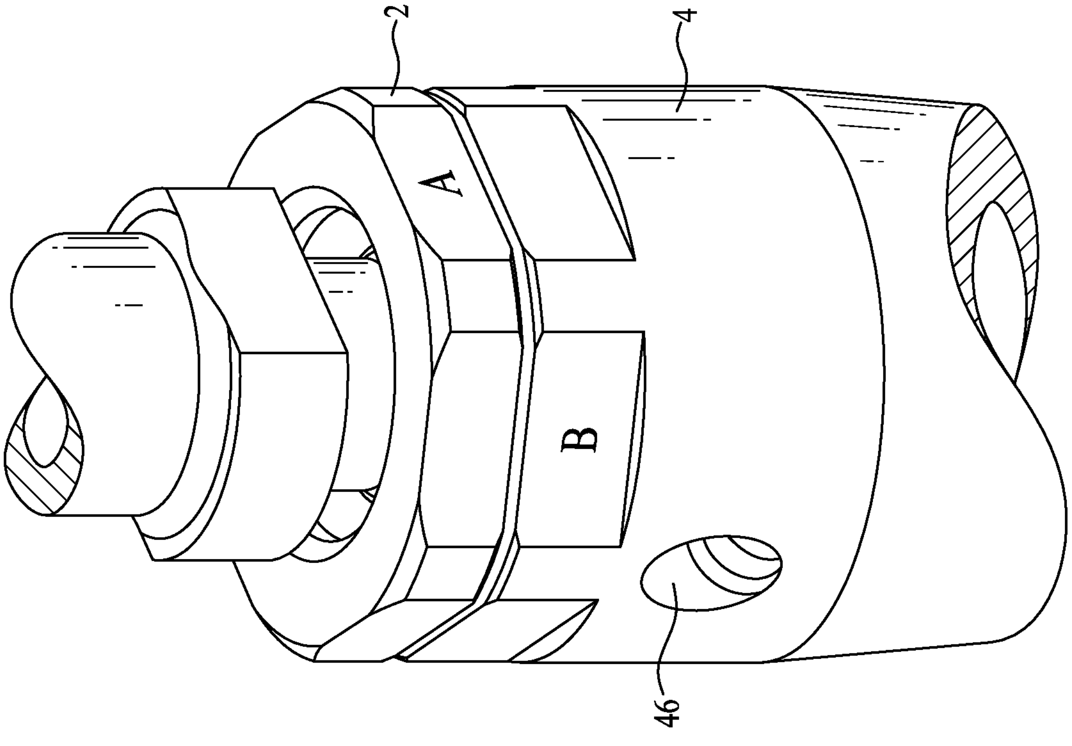

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No. PCT/US13/57105

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - B24B 1/00, B24C 3/00, and B24C 7/00 (2014.01)

USPC - 451/36, 38, 41, 75, 99

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)

IPC(8) Classification(s): B24B 1/00, B24C 3/00, and B24C 7/00 (2014.01)
USPC Classification(s): 451/36, 38, 41, 75, 99

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)

MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C,B, DE-A, DE-T, DE-U, GB-A, FR-A); IP.com; Google/Google Scholar; DialogPRO; Searched Terms Used: cutting, head, abrasivejet, thread, lead, pitch, external, jet, abrasive

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,018,670 A (CHALMERS EJ) May 28, 1991; figure 2; column 3, lines 20-40	1-24
Y	US 6,119,541 A (ROBINSON K) September 19, 2000; figure 5; column 1, lines 40-50	1-24
A	US 2009/0258582 A1 (MILLER DS) October 15, 2009; figure 3; paragraph [0111]	1-24

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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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
04 January 2014 (04.01.2014)	15 JAN 2014

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