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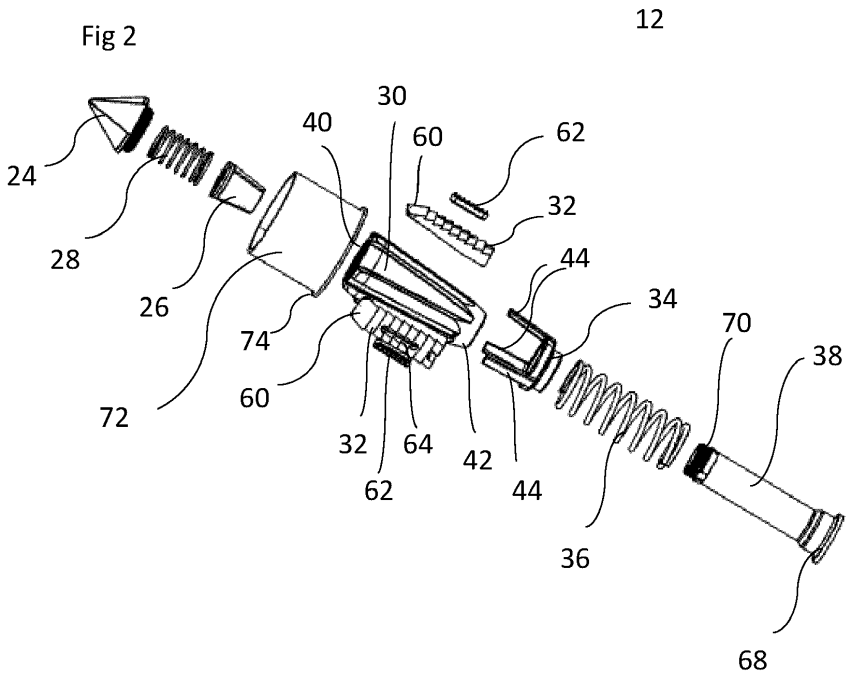
(54) **AN ANCHOR FOR A ROCK BOLT AND A ROCK BOLT**

(57) An anchor 12 for a rock bolt 10. The anchor 12 being connectable to a cable or rod 14 and being expandable between a hole insertion condition and a hole anchor condition. The anchor 12 has at least one gripper 32 that is expandable outwardly from the insertion condition of the anchor 12 to the anchor condition of the anchor 12 for gripping the facing surface of a hole in which the anchor 12 is installed. The gripper 32 comprises a body part 60 and a gripper portion 62, the body part 60 being formed from a hard material and the gripper portion 62 being formed of a material having a greater hardness than the body part 60. The gripper portion 62 has an outer facing gripping surface 66 that projects beyond the body part 60 in the direction of outward expansion of the gripper 32.

Fig 2



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Description

Technical Field

[0001] The present invention relates to a rock bolt for use in rock strata to support the rock strata against collapse or failure, and to an anchor for use in such a rock bolt.

Background of Invention

[0002] The discussion of the background to the invention that follows is intended to facilitate an understanding of the invention. However, it should be appreciated that the discussion is not an acknowledgement or admission that any aspect of the discussion was part of the common general knowledge as at the priority date of the application.

[0003] Rock bolts are used for reinforcing rock strata by inserting the bolt within a hole drilled into the rock strata and fixing the bolt within the hole. Bolts can be fixed within a hole by frictional engagement with the wall of the hole or they can be embedded within the hole within grout or resin, or both. The trailing end of a rock bolt will usually extend out of the open end of the hole and a rock plate can be attached to the trailing end and can be tightened to press firmly against the rock face that surrounds the hole opening. The fixing of the bolt within the hole resists egress of the bolt from the hole and rock plate supports the rock face against fracture and displacement. Safety mesh can be installed broadly across the rock face by anchoring the mesh to multiple rock bolts. In this manner, the rock bolts support the rock strata against fracture and collapse and the safety mesh can restrain any dislodged pieces of the rock strata. The use of bolts and mesh is widespread in the underground mining industry to protect workers and equipment in underground mines and tunnels from strata fracture.

[0004] Rock bolts can employ a rigid or flexible tendon that extends between leading and trailing ends of the rock bolt. A rigid tendon can comprise a bar or rod, or a tube, such as a longitudinally split tube. Other rock bolts employ a flexible tendon, which is usually a cable. Rock bolts can employ an anchor or expander at a leading end and a rock plate at the opposite and trailing end. The anchor or expander is used to engage the rock bolt against facing surfaces of the drilled hole. An expander can be used inside a split tube to expand the diameter of the tube, while an anchor can be itself expandable to engage the facing surfaces of the drilled hole. The anchor or expander can be activatable once the rock bolt is properly positioned within the drilled hole.

[0005] Rock bolts that employ a rod, bar or tube typically have a length of between 1.8m to 3m. In underground tunnelling, the length of the rock bolt is generally limited by the room available within the tunnel. In underground mining, the available room often precludes the use of rock bolts that have a length greater than 3m. In underground tunnelling in general, the available room often precludes the use of rock bolts that have a length greater than 6m.

[0006] Rock bolts that employ a cable are usually used where the depth of the hole into which the rock bolt is installed exceeds the maximum length of rock bolts that employ a rod, bar or tube. For example, rock bolts that employ a cable can be used in holes having a depth of 10m or more. For these forms of rock bolts the cable can be unrolled from a cable reel, so that any length of cable can be used.

[0007] Rock bolts that employ a cable are not rigid and therefore they must be pushed into the hole without significant frictional resistance. In some installations, the hole is empty, while in other installations, cement grout is pumped into the hole before the rock bolt is inserted and once the hole is sufficiently filled with grout, the cable bolt is fed from a reel into the hole, pushing through the grout. Once sufficient cable has been fed into the hole, the trailing end of the cable is severed, usually leaving about 0.3m extending from the opening of the hole.

[0008] Cable rock bolts can include an anchor at the leading end. Where the hole is filled with grout, the anchor can be pushed through the cement grout to the inner end of the hole or to the appropriate position within the hole. Alternatively, the anchor can be omitted so that the leading end of the bolt is simply the leading end of the cable. Where an anchor is employed, the anchor is provided to engage against the facing surface of the hole and to grip the facing surface so as to anchor the leading end of the rock bolt within the hole. The anchors are normally expandable anchors that have an insertion condition and a hole anchor condition, whereby the anchor travels into the hole in the insertion condition and once the anchor is positioned at the correct depth within the hole, the anchor is activated by expansion to the anchor condition, to grip the facing surfaces of the hole. The diameter of the anchor in the insertion condition is typically at least slightly less than the diameter of the hole, so that the anchor can travel into the hole without significant frictional resistance. Once the anchor has reached the installation position, expansion of the anchor to a greater diameter allows the anchor to engage and grip facing surfaces of the hole to anchor the leading end of the cable and the rock bolt.

[0009] Activation of the anchor to the anchor condition provides an immediate connection of the bolt within the hole, so that 1) the rock bolt can be loaded immediately by application of a rock plate at the trailing end of the rock bolt against the rock strata surrounding the opening of the hole and 2) the cable is secured from falling out of the hole as soon as the anchor is activated. The rock bolt thus immediately provides strata support and secures the cable within the hole, allowing immediate re-entry to the tunnel. Alternatively, if the anchor is omitted and the cable is secured in place by cement grout, the cable bolt is not operational and the cable is not secured within

the hole, until the cement grout has cured. Fear of the cable falling out of the hole commonly stops miners travelling through that part of the excavation (tunnel) until the grout sets (approximately 12 hours). The present invention relates to rock bolts that include an anchor at the leading end.

[0010] Rock bolts are installed in rock strata of varying consistency. Some rock strata is considered to be soft, whereas other rock strata is considered to be hard, and of course there is rock strata across the spectrum in between. Different rock bolts are suitable for rock strata of different hardness. Where the rock strata is soft, anchors can be configured with teeth or knurling to grip the facing surface of the hole by biting into the facing surface. In order to avoid the anchor crushing the facing surface, in softer rock strata, anchors are configured to be longer than in harder rock strata, to increase the contact area with the hole wall, aiming to decrease the contact pressure to below the upper compressive strength of the rock. The anchor can deform the hole and create a ledge or step below the anchor in a direction towards the open end of the hole, which resists the anchor being pulled out of the hole. That is, where the anchor is expanded into engagement with the facing surface of the hole, the diameter of the hole is enlarged by that engagement whereas below the anchor, the diameter of the hole remains as drilled.

[0011] A form of rock bolt of the above kind is disclosed in European Patent EP0068227 in the name of Upat GmbH & Co. In EP0068227, a profiled insert is connected to the leading end of a shank that is inserted into a drilled hole. Ahead of the insert is a spreading wedge which moves with the profiled insert as the shank is fed into the hole. When the spreading wedge reaches the inner end of the drilled hole, further insertion of the shank and the profiled insert causes the profiled insert to engage the spreading wedge and to spread radially outwardly. The wall of the hole is crushed or eroded in the region of the profiled insert to create an undercut of greater diameter than the hole immediately below the profiled insert, thus firmly anchoring the profiled insert and thus the shank within the hole.

[0012] Another similar form of rock bolt of the above kind is disclosed in European Patent EP0102914, again in the name of Upat GmbH & Co.

[0013] Conversely, where the rock strata is hard, or very hard, (such as crystalline rock, which is igneous rock and is considered hard, in contrast to clastic rock, which is sedimentary rock and is considered soft) for example, then the anchor may not be able to bite into the facing surface of the hole, but rather, will engage the hole by frictional engagement only. Hard, or very hard rock strata can be defined in various ways. For example, one suitable reference is 'Ground Support for underground mines' by Potvin and Hadjigeorgiou, 2020, ISBN 978-0-9876389-5-3, Australian Center for Geomechanics from page 8. A more basic definition would be that sedimentary rock would be regarded as soft, while igneous rock would be regarded as hard. Alternatively, strata <100 MPa (uniaxial compressive strength) would be regarded as soft, whereas if it were >100 MPa it would be regarded as hard. For example, coal, shale and mudstone are regarded as soft, while granite, basalt and andesite are regarded as hard.

[0014] If the rock is hard or very hard and the anchor engages by frictional engagement only, the anchor may not be firmly fixed within the hole. In addition, in this hard rock strata, often the surface of the drilled hole will be smooth before the anchor is inserted, making frictional engagement between the anchor and the facing surface of the hole again, less effective. Still further, if the hole has been filled with cement grout, before the grout cures, it can act as a lubricant between the anchor and the facing surface of the hole, reducing even further the effective frictional engagement between the anchor and the facing surface of the hole. Thus, in these circumstances, the frictional engagement between the anchor and the facing surface of the hole may not anchor the leading end of the rock bolt in the hole to the desired amount.

[0015] The present invention aims to provide a new form of anchor that can provide an improved anchored connection between the anchor and the facing surfaces of a hole, particularly where the hole is drilled in hard, or very hard rock strata.

[0016] The present invention has been developed specifically in relation to rock bolts that employ cables rather than rigid rods, bars or tubes and so it will be convenient to describe the invention in relation to those forms of rock bolt. It should be appreciated however, that the invention could apply to rock bolts that employ a rod, bar or tube.

Summary of Invention

[0017] According to one form of the present invention, an anchor for a rock bolt is provided whereby the anchor is connectable to a cable or rod and is expandable between a hole insertion condition and a hole anchor condition, the anchor having:

at least one gripper that is expandable outwardly from the insertion condition of the anchor to the anchor condition of the anchor for gripping the facing surface of a hole in which the anchor is installed,

the gripper comprising a body part and a gripper portion, the body part being formed from a hard material, the gripper portion being formed of a material having a greater hardness than the body part, the gripper portion having an outer facing gripping surface that projects beyond the body part in the direction of outward expansion of the gripper.

[0018] The term "hardness" can be defined as the ability of a material to resist localized plastic deformation. The hardness of a material can be measured by using well known tests such as the Vicker's, Brinell or Rockwell

hardness tests.

[0019] The gripper portion is of a harder material than the body part. In prototype forms of the present invention, the gripper portion is formed from cemented tungsten carbide and the body part is formed from AISI 4140 steel, i.e. Cr-Mo steel. Of course many other materials could be employed and some alternatives will be identified later herein. The body part can be forged, cast or machined.

[0020] At the time of filing this application, the mechanism or interaction between the gripper portion and the facing wall of a drilled hole into which the anchor has been inserted or installed, is expected to be that the gripper portion is to break or penetrate into the facing wall, such as to crush, crumble, fracture or pulverise the facing wall of the drilled hole so that the gripper can grip the facing wall. The gripper might grip the facing wall by the gripper portion gripping the facing wall once the gripper portion has broken into the facing wall, or the body part might grip the facing wall once the gripper portion has broken into the facing wall, or both of the body part and the gripper portion might have a gripping function once the gripper portion has broken into the facing wall.

[0021] The outer facing gripping surface of the gripper portion will be shaped to break into the facing wall. For this, the outer facing gripping surface might have a keying shape, or a peaked or serrated shape. It is not intended to damage the facing wall significantly. The intention is to allow the outer facing gripping surface to penetrate into the facing wall just enough for a grip to be established. This might mean that the peaks of the outer facing gripping surface only slightly penetrate into the facing wall. Pressure concentration of the peaks of the outer facing gripping surface against the facing wall will allow the penetration or purchase with sufficient expansion load, by the contact pressure being greater than the compressive strength of the rock of the facing wall. If the area of contact increases, such as the peaks penetrate into the facing wall, or if the body part about the gripper portion engages the facing wall, then the pressure concentration will fall. When the pressure concentration falls below that of the compressive strength of the rock, there will be no further penetration. More discussion of this aspect of the present invention will be made later herein.

[0022] The present invention also provides a rock bolt that has an anchor as above described. Such a rock bolt will comprise a tendon that is connected to the anchor, whereby the tendon can be a bar or rod, or a tube, such as a longitudinally split tube, or a cable, such as a steel cable. The tendon can extend to a rock plate installation at the trailing end of the tendon, whereby the rock plate installation can comprise a nut that threads onto the trailing end of the tendon, or a barrel and wedge arrangement that frictionally grips the trailing end of the tendon. In either case, the nut or the barrel and wedge arrangement can bear against a rock plate and can press the rock plate into firm engagement with the face of the rock strata into which the rock bolt is installed. The rock plate installation can also include facility for connection of safety mesh.

[0023] An anchor according to the present invention can be connected to the leading end of a tendon prior to inserting the anchor into a drilled hole. Where the tendon is cable, the anchor can be attached or connected to the end of a bulk roll of cable that is being fed from a reel and thereafter inserted or fed into a previously drilled hole. The hole typically will be filled already with a wet cement grout so that the anchor and the cable push into and through the grout until the anchor reaches the inner end of the hole. Advantageously, once the anchor is in position, the tendon can be tensioned to activate the anchor and the rock bolt can provide instant or immediate support to the rock strata in advance of the grout curing and setting the tendon within the hole and the cable is secured from falling out of the hole as soon as the anchor is activated. The expectation is that in hard rock strata where previously significant pretension load could not be provided due to the difficulty in anchor engagement with the wall of the hole (as explained above), a rock bolt that includes an anchor according to the present invention will be able to be pretensioned to resist up to 100kN prior to the grout curing. This instant or immediate support, including securing the tendon, allows activity to take place within the supported area straight after the rock bolt has been tensioned rather than having to wait at least 12 hours for the grout to cure.

[0024] The gripper portion can be attached to the body part, such as by mechanical fastening, fusion fastening such as brazing, or as a coating applied to a surface of the body part. The outer facing gripping surface of the gripper portion can comprise the entire gripping surface of the gripper, or it can be a section of, or a sub-section of the gripping surface of the gripper.

[0025] Where the gripper portion is a section of, or a sub-section of the gripping surface of the gripper, the body part of the gripper can also have an outer facing gripping surface, so that the gripping surface of the gripper comprises the two gripping surfaces of the gripper portion and the body part. In this arrangement, the gripper portion gripping surface is formed of a material having a greater hardness than the body part gripping surface. In this arrangement, the gripper portion can be attached to the body part so that the gripper portion gripping surface projects from the body part gripping surface, and so that the gripper portion gripping surface will engage the facing surface of the hole before the body part gripping surface engages the facing surface of the hole. This engagement of the facing surface of the hole by the gripper portion gripping surface before the body part gripping surface engages the facing surface of the hole allows the gripper portion to break the facing surface of the hole wall (such as by crushing, crumbling, fracturing or pulverising the facing surface as described earlier herein) in the region of the gripper portion gripping surface, including beyond the gripper portion gripping surface, to allow both the gripper portion gripping surface to penetrate into the facing surface, as well as the body part

gripping surface, so that the gripper itself grips and holds against the facing surface.

[0026] The gripper portion can be an insert or inserts for example, that is or are inserted into the body part gripping surface.

[0027] The gripper portion can be a single portion, or it can be 2 or more, or multiple portions. As a single portion, the gripper portion can have one or more peaks or serrations. Alternatively, the gripper portion can be formed of two or more separate units that each have one or more peaks or serrations. The units can be square, rectangular or cylindrical units.

[0028] The gripper portion can be formed of any suitable material that has a greater hardness than the body part and for example, gripper portion can be formed from carbide. The carbide can be cemented tungsten carbide as indicated earlier herein. The hardness of the cemented tungsten carbide could be in the region of 1000 HV to 2000 HV (Vickers hardness). More preferably the hardness of the cemented tungsten carbide is between 1000 HV and 1500 HV and most preferably the hardness is between 1100 HV and 1350 HV. Other hard materials include tool steels, high speed steels, diamond, boron carbide, and like materials. The body part and the gripper portion can be selected based on the hardness of the rock the rock bolt is to be installed in, so that while steel might be most commonly used for the body part, because of its relatively low cost and ease of manufacture, the gripper portion might vary from harder metals to carbides.

[0029] An anchor according to the present invention comprises at least one gripper, but preferably 2, 3 or 4 grippers. Where the anchor comprises 2, 3 or 4 grippers the grippers can be spaced apart generally equidistantly about a longitudinal axis of the anchor and can be equally spaced away from the axis. In one form of the present invention, the anchor comprises 3 grippers.

[0030] Where the gripper comprises a body part that has an outer facing gripping surface, that surface can have any suitable profile such as a toothed, knurled, peaked or barbed profile, or a sawtooth profile. In some forms of the invention, a sawtooth profile is provided and the inclination of the teeth of the profile is away from the direction of insertion of the anchor into a drilled hole, so that if the peaks of the teeth of the sawtooth profile engage the wall of the hole during insertion of the anchor into the hole, the teeth can slide relative to the wall without biting into the wall. The sawtooth profile can extend for the full width of the body part, which may also be the full width of the gripper and for substantially the full length of the body part or of the gripper.

[0031] The gripper portion can be formed as an insert that is connected to the body part in any suitable manner. In some forms of the invention, the body part has a recess in the body part gripping surface and the insert is fixed within the recess. The insert can be fixed within the recess in any suitable manner such as by brazing, or welding or gluing. Alternatively, the insert can be a press fit or a friction fit within the recess. Where the body part is elongate, the a leading end of the body part gripping surface, or the trailing end, or generally centrally between the leading and trailing ends. The recess can be provided towards one or other of the opposite sides of the body part or generally centrally between the opposite sides.

[0032] The recess can be a blind recess so that it has a base and a peripheral wall upstanding from the base. The insert can be supported on the base of the recess save for any braze, weld or glue or other connection that might be interposed between facing surfaces of the insert and the base. In this arrangement, when the gripper is expanded outwardly to engage or grip the facing surface of a hole in which the anchor is installed, the insert is supported to push against the facing surface of the hole by the recess base.

[0033] The peripheral wall can extend fully about the base or partially about the base. For example, the insert can have a leading end and a trailing end and side walls extending between the leading and trailing ends, with the leading and trailing ends being aligned generally with the axis of insertion of the anchor into a hole in which the anchor is to be installed. In this form of the invention, the peripheral wall can be a close fit about at least the leading end and the side walls of the insert, so that when the insert gripping surface engages the facing surface of the hole in which the anchor is installed, the peripheral wall resists relative movement of the insert within the recess from side to side as well as in one axial direction. That axial direction will be the direction in which the insert would tend to move relative to the body part when the anchor is engaged with the facing surface of a hole in which the anchor is installed and the rock bolt is tensioned.

[0034] Alternatively, the peripheral wall can extend fully about the base and be a close fit about the leading and trailing ends and the side walls of the insert. In this form of the invention, the peripheral wall resists relative movement of the insert within the recess in any direction. In this form of the invention, connection of the inset to the body part is facilitated by the insert being placed and secured within the recess prior to brazing, welding or gluing or the like. The brazing process can involve applying a fluxing agent into the recess and loading a braze alloy the into the recess and applying further fluxing agent as required. The insert can then be placed on top of the braze alloy and then the gripper as assembled can be heated, such as by conductive heating by electric coil, or in an oven.

[0035] Each of the body part and the insert can be elongate and the elongate axis of the insert can be generally aligned with the elongate axis of the body part. The size of the body part can be greater than the insert and the gripping surface of the body part can have a greater area than the gripping surface of the insert. The ratio of the gripping surface of the body part and the insert can be in the order of about 10:1, or 8:1, or 6:1, or 4:1 or 2:1 for example. In prototypes developed to date, the ratio is in the order of about 7.2:1.

[0036] The gripper portion can be attached to the body

part to project outer facing gripping surface of the gripper portion from the body part gripping surface any suitable amount. The projection of the gripper portion from the body part gripping surface can vary because the body part gripping surface itself will usually vary in height based on the profile of the gripping surface. For example, if the body part gripping surface has a sawtooth profile, the profile will include peaks and troughs, so that the gripper portion will project from the body sawtooth profile a greater amount at a trough of the profile and a lesser amount at a peak of the profile.

[0037] Where the profile of the body part gripping surface varies in height, say from a rear surface of the body part, the gripper portion gripping surface can also vary in order that the projection of the from the body part gripping surface is consistent across the body part gripping surface. However, in some forms of the invention, the gripper portion gripping surface has a constant or consistent height or depth and so the projection of the gripper portion from the body part gripping surface varies.

[0038] What is important in this form of the invention is that the gripper portion gripping surface projects from the body part gripping surface sufficiently so that insert gripping surface engages the facing surface of a hole in which the anchor is installed before the body part gripping surface engages the facing surface of the hole and that there is sufficient advance engagement of the gripper portion gripping surface with the facing surface of a hole to allow the gripper portion gripping surface to break or penetrate into the facing surface (by crushing, crumbling, fracturing or pulverising the facing surface as described earlier herein) so that the gripper portion gripping surface can grip the facing surface. Where the body part has a gripping surface in addition to gripper portion gripping surface, once the gripper portion has acted on the facing surface of the hole in the manner described, the body part gripping surface may then engage and grip the facing surface. This is different to where the gripper consists of a steel body part only when used with hard rock that has a greater compressive strength than steel.

[0039] With a gripper in accordance with the invention, the facing surface of the rock will be changed by the gripper portion (broken or penetrated or as otherwise described herein) and then gripping of the rock face can be by a combination of the gripper portion and the body part, or just by the body part. In that latter respect, in some forms of rock, generally softer rocks, the body part will have the primary gripping function once the surface of the rock face has been changed or altered by engagement with the gripper portion. It is even possible that the gripper portion will have the primary gripping function if the rock face is sufficiently hard that the body part gripping surface does not approach the facing surface of the rock sufficiently to engage and grip the facing surface. It is expected that this would be very hard rock.

[0040] It is expected that the gripper portion gripping surface will tend to fracture or change the facing surface beyond the area of the gripper portion gripping surface, so that the facing surface around the gripper portion gripping surface will also fracture, crush or crumble to some extent, so that the fractured, crushed or crumbled surface will be broader than just where the insert gripping surface engages the facing surface and that broader fractured, crushed or crumbled surface will allow the body part gripping surface to subsequently grip, bite or penetrate into the facing surface, thus allowing the gripper to grip the facing surface. The gripper will thus potentially grip the facing rock surface across each of the gripper portion gripping surface and the body part gripping surface.

[0041] The body part gripping surface and the gripper portion gripping surface can have the same gripping profile, with the gripping profile of the gripper portion projecting from the gripping profile of the body part gripping surface. Example gripping profiles for both can be toothed, knurled or barbed profiles, or sawtooth profiles. Alternatively, the body part gripping surface and the gripper portion gripping surface can have having different gripping profiles. In some forms of the invention, the gripping profile of the body part gripping surface is a sawtooth profile, while the gripping profile of the gripper portion gripping surface is formed from multiple projections, for example conical, frusto-conical or pyramid-shaped projections, whereby apexes or peaks of the projections project from the body part gripping surface. The gripping profile of the gripper portion gripping surface can include a few as two projections, although in some forms of the invention, four or more projections are provided. These projections can be provided in any suitable formation, such as a square formation, or in a column. In some forms of the invention, two generally parallel rows of projections are provided. In some forms of the invention, each row includes the same number of projections and for example, each row can include 3, 4, 5, 6 or 8 projections, or more.

[0042] As indicated earlier herein, the gripper portion can be formed from multiple units, such as cylindrical inserts that each have a gripping profile and that are friction fitted to the body part, or otherwise attached to the body part. The gripper portion could be formed from one or more projections, nodules or buttons for example. These could be attached to the body part, such as to a platform or base of the body part. These could be cemented tungsten carbide projections, nodules or buttons and the platform or base could be formed within the body part gripping surface, such as in an area where any gripping profile has been removed for attachment of the projections, nodules or buttons.

[0043] Where the gripper portion gripping surface has a multi-peaked profile, such as formed from multiple nodules or buttons, or conical, frusto-conical or pyramid-shaped projections, at least the distal ends or apexes of the projections will project from the body part gripping surface. The projections can be three-sided or four-sided projections, or circular or curved, or arrow shaped for example. Apexes or distal ends of the projec-

tions can be pointed or sharp, or blunt such as convexly curved or even flat. The projections can be any suitable shape that can be formed from a material having a greater hardness than the body part, carbide for example, and that can penetrate into a hard rock wall.

[0044] Much of the discussion above has focussed on the construction of the gripper or grippers of the anchor of the present invention. Beyond the gripper or grippers, the anchor is otherwise also unique in the manner of its construction. The anchor itself will now be discussed in more detail.

[0045] The anchor comprises a connector for connecting to a tendon, which, as will be appreciated from the discussion above, is likely to be a cable for most applications of the present invention, but which could also be a rod, bar or tube, such as a split tube. In some forms of the invention, the connector is a barrel and wedge connector that attaches to the leading end of the tendon. The barrel part of the connector can be an internal wall of a body section of the anchor which is tapered, or the barrel can be a separate component that is mounted within the anchor. The body section of the anchor can be a mandrel. The connector can be movable within the barrel so that it can move in a first wedge opening direction to a position in which the wedges are open sufficiently to receive the leading end of the tendon and can then move in a second and opposite closing direction to close about and grip the leading end. The connector can be housed in the anchor for movement longitudinally of the anchor between leading and trailing ends of the anchor and the connector can be biased towards the second direction so that as soon as the connector has moved in the first direction sufficiently to open widely enough to accept the leading end of the tendon, the connector is biased in the second direction to grip the leading end. The connector can be housed in the anchor so that as the tendon is tensioned the connector moves further in the second direction to progressively more firmly grip the leading end, so that the gripping load continues to increase as the tension load applied to the tendon is increased.

[0046] The connector can be housed in a leading end of the anchor and the leading end can be closed by cap which can have a pointed shape to facilitate entry of and passage of the anchor into and through a drilled hole. The cap can be conical, frusto-conical or pyramid-shaped for example. A spring can be mounted between the cap and the connector to bias the connector in the second direction of movement as discussed above. The cap can connect to the body section of the anchor.

[0047] The outer surface of the of the anchor can be tapered from a larger diameter leading end to a smaller diameter trailing end. The gripper or grippers can be mounted to the outer surface of the body section, so that relative to the body section, the gripper or grippers can shift or move between an installation position at the smaller diameter trailing end and an expanded position at the larger diameter leading end. The gripper or grippers can be mounted to the outer surface of the body section in any suitable manner and in some forms of the invention, the gripper or grippers are moveably mounted to the body section by a sliding keyed arrangement and so that the gripper or grippers are connected to the body section against removal, but the gripper or grippers can slide relative to the body section between the smaller diameter trailing end and the larger diameter leading end. In some forms of the invention, the body section includes a T-shaped keyway and the gripper or grippers include a complementary T-shaped key extending from a rear face of the gripper or grippers.

[0048] The anchor can include an abutment to limit movement of the gripper or grippers in the direction of the smaller diameter trailing end. In some forms of the invention, the abutment can be movable so that even though the gripper or grippers is in abutting contact with the abutment, the abutment can allow further movement of the gripper or grippers in the direction of the smaller diameter trailing end. This can be beneficial to allow the gripper or grippers to retract along the tapered surface of the body section of the anchor sufficiently to allow ease of insertion of the anchor into a drilled hole where the diameter of the drilled hole causes the gripper or grippers to scrape against the facing surface of the hole as the anchor is inserted. The abutment can be biased in the direction towards the larger diameter end of the body section so that once the anchor has reached the installation position, the gripper or grippers are biased into engagement with the facing surface of the hole. The abutment can be formed as a bracket that includes one or more extending fingers or arms, distal ends of which abut against the gripper or grippers. The gripper or grippers can have a slot formed in the trailing end to accept or receive a leading end of the finger or arm to secure each gripper relative to the finger or arm.

[0049] The gripper or grippers can disconnect from the abutment as the rock bolt is tensioned and the gripper or grippers move relative to the body section towards the larger diameter leading end of the body section, depending on how far the gripper or grippers move under the tension exerted on the rock bolt.

[0050] A rock bolt according to the present invention includes a tendon having a leading and trailing end and an expandible anchor attached to the leading end, whereby the anchor is as hereinbefore described. The leading end of the tendon is connected to the anchor, such as by the barrel and wedge arrangement discussed earlier herein. That connection is made before the anchor is inserted into a drilled hole and in particular, if the tendon is a cable, the anchor is attached to the free end of the cable and the cable is fed from a reel to feed the anchor and cable into the hole.

[0051] Once the anchor has been positioned within the hole, the cable reel from which the cable is fed, can tighten the cable to expand the anchor into engagement with the wall of the hole, ie set the anchor. This is not the final tension load applied to the cable, but is an initial load. The cable can then be severed from the reel and with the

anchor set in the hole, the cable attached to the anchor cannot fall out of the hole. The installation machinery can then move to the next point of rock bolt installation while other personnel and machinery can immediately re-enter the area of the rock bolt to further tighten the cable and to apply a rock plate assembly to the trailing end of the cable. This system advantageously allows bolting to occur by forward movement of bolting machinery into the excavated area being bolted, which is desirable and which is the reverse of which happens in current bolting arrangements.

[0052] The rock plate assembly can be of any suitable kind. The cable can be tensioned causing the anchor to grip the facing internal wall of the hole by the gripper or grippers expanding into contact with the facing surface of the hole. Where the hole is drilled in hard rock, or very hard rock, the carbide of the insert will cause the rock surface to crush, crumble or fracture, allowing both the insert gripping surface and the body part gripping surface to grip the facing surface.

[0053] Once the facing surface of the hole has been engaged by the gripper portion gripping surface, and the body part gripping surface has subsequently engaged the facing surface, the major gripping load may be provided by the body part of the gripper or grippers, rather than the gripper portion. That is, in some rock strata, the function of the gripper portion may be to initially engage the facing wall surface to treat, damage or affect the facing surface. The treatment, damage or effect on the facing surface is expected to be crushing or fracturing the facing surface, but it may manifest differently and indeed, the level of any crushing or fracturing may be very low, even to the point that the wall surface or scratched or roughened as compared to pre-engagement by the gripper portion. The intention at this stage is not to damage the facing surface too much. In hard crystalline rock it is expected there will be some crushing within and adjacent the gripper portion, but the level of that damage is intended to be just enough for the gripper portion to 'key' into the facing surface to grip the facing surface. Where the gripping surface of the gripper is the combination of the gripper portion gripping surface and the body part gripping surface, the gripper portion gripping surface is intended to project beyond the body part only so that the gripper portion gripping surface can act on the facing wall surface for a short period to treat, damage or affect the facing surface, before the body part gripping surface engages the facing surface and the contact pressure of the gripper against the facing surface lowers, preferably to below the compressive strength of the rock, by the increased surface area of the gripper engaging the facing surface.

[0054] It follows that the intention is prevent significant or even catastrophic damage to the rock surface in the area the anchor expands against. Tests conducted to date show that there can be very little damage to a facing surface, even though an improved grip of the anchor within the hole is produced.

Brief Description of Drawings

[0055] In order that the invention may be more fully understood, some embodiments will now be described with reference to the figures in which:

Figure 1 is a perspective view of a rock bolt according to a first embodiment of the present invention.

Figure 2 is an exploded view of the anchor of the rock bolt of Figure 1.

Figure 3 is a perspective view of a gripper of the anchor of Figure 2, in abutting contact with a bracket.

Figure 4 is a perspective view of a mandrel of the anchor of Figure 2.

Figure 5 is a perspective view of a gripper of the anchor of Figure 2.

Figure 6 is a side view of the gripper of Figure 5.

Figures 7 to 9 show alternative gripper constructions.

Detailed Description

[0056] Figure 1 is a perspective view of a rock bolt 10 according to one embodiment of the present invention and comprises an anchor 12, a tendon in the form of a cable 14 and a rock plate installation comprising a rock plate 16 and a barrel and wedge arrangement 18. The cable 14 is shown broken to indicate that it can be of any length.

[0057] It will be appreciated that the rock bolt 10 is intended to be installed in a hole that is drilled within a body of rock or a rock strata. The anchor 12 is provided at the leading end of the rock bolt 10 and is fed into the hole by bolting equipment in connection with a leading end of the cable 14. The cable 14 is fed from a cable reel. The anchor 12 is fed into the hole to be positioned usually at the inner end of the hole and the cable 14 extends rearwardly from the anchor 12. With the anchor 12 and the cable 14 installed in the hole, the anchor 12 can be initially activated by the bolting equipment pulling on the cable 14. With the anchor 12 activated and thus anchored within the hole, the cable 14 is also secured so that it can be severed at the open end of the hole, disengaging it from the bolting equipment and usually leaving about 300mm extending out of the opening of the hole. The bolting equipment can then move onto the next bolting location, while personnel and tensioning machinery can move into place to apply the rock plate assembly to the trailing end of the cable 14 and to then apply the operating or working tension to the cable 14. This process is highly advantageous, as personnel are prohibited from approaching the installed rock bolt if the cable of the bolt is loose and can fall out of the hole. The present invention

can initially secure the cable within the hole sufficiently to allow personnel to approach while the bolting equipment moves to the next upstream bolting location.

[0058] The rock plate 16 has a central opening through which the trailing end of the cable 14 extends and the barrel and wedge arrangement 18 is attached to the cable 14 to the side of the rock plate 16 shown in Figure 1.

[0059] The rock bolt 10 can be installed within an empty hole, or in a hole that has been filled with a cement grout or resin, so that the anchor 12 and the cable 14 pushes through the grout as it is installed within the hole.

[0060] The barrel and wedge arrangement 18 can be of a known form that attaches to the trailing end of the cable 14 and which grips the trailing end and bears against a facing surface of the rock plate 16. The barrel and wedge arrangement 18 is constructed with an outer sleeve 20 which accommodates inner wedges (not visible in Figure 1), in a manner that the cable 14 can be pulled through the wedges in the direction of arrow A, but which grips the cable 14 to prevent it from moving in the opposite direction. The barrel and wedge arrangement 18 thus allows the cable 14 to be tightened by pulling it in the direction of arrow A, which results in the arrangement 18 pressing the rock plate 16 into firm engagement against a facing rock strata.

[0061] Figure 2 is an exploded view of the anchor 12. The anchor 12 comprises a cap 24, wedges 26, a first spring 28, a body section, anchor body or mandrel 30, shells or grippers 32, a bracket 34, a second spring 36 and a tube 38.

[0062] To connect the cable 14 to the anchor 12, the leading end of the cable 14 extends through the anchor 12 and into the wedges 26. The leading end of the cable 14 can push into the wedges 26, but if the cable 14 is pulled in the opposite direction, the wedge 26 grips the leading end of the cable 14 and securely connects to it.

[0063] The wedges 26 are accommodated within the mandrel 30 and the proximal end of the cap 24 connects to the leading end of the mandrel 30 by screw thread connection. One end of the spring 28 bears against the cap 24, while the other bears against the wedges 26 so that when the leading end of the cable 14 is pushed into the wedges 26, the wedges 26 can push against the spring 28 to open and accept the leading end of the cable 14 and thereafter the spring 28 biases the wedges 26 into gripping engagement with the cable 14. That gripping engagement increases as the cable is pulled in the direction A of Figure 1.

[0064] The mandrel 30 tapers from the leading end 40 the trailing end 42. The bracket 34 fits to the trailing end 42 and includes three arms 44 that extend toward the leading end 40 as shown in Figure 1. There is one arm 44 for each of the grippers 32. As shown in Figure 3, the grippers 32 have a rear end 46 that includes a recess or slot 48 to accept or receive a leading end 52 of the arms 44. The slot 48 has an inner end 50 against which the leading end 52 of each arm 44 abuts.

[0065] The leading ends 47 of the grippers 32 also include a key 54 that is formed in a T- shape and that is in sliding connection with a complementary shaped keyway 56 as shown in Figure 4. The keyway 56 is open at the leading end 40 of the mandrel 30 and is closed at the trailing end 42, so that the key 54 can be fitted to the keyway 56 at the leading end 40 of the mandrel 30, but the key 54 cannot slide out of the keyway 56 at the trailing end 42. The grippers 32 can thus slide longitudinally relative to the mandrel 30. Travel of the grippers 32 is prevented in the direction towards the trailing end 42 of the mandrel 30 either by reaching the end of the keyway 56 at the trailing end 42, or upon abutment between the leading end 52 of the arms 44 with the inner end 50 of the slots 48. As will be described later herein, the grippers 32 move away from the bracket 34 in a direction towards the leading end 40 of the mandrel 30 during expansion of the anchor 12 by the grippers 32 sliding longitudinally relative to the mandrel 30 by sliding movement of the key 54 within the keyway 56.

[0066] Figure 5 illustrates a gripper 32 in isolation and clearly shows that the front surface 58 has an outer facing gripping surface formed in a sawtooth profile. The sawtooth profile is formed in a body part 60 of the gripper 32 that is formed of a material, such as steel. The body part 60 has a central recess, slot or channel (hereinafter "recess") within which is disposed a gripper portion in the form of an insert 62. The insert 62 can be formed of a carbide material. In the exploded view of Figure 2, the carbide insert 62 is shown separate from the body part 60 and in one of the grippers 32, the central recess 64 is visible. The insert 62 is fixed within the recess 64 by any suitable arrangement, such as by brazing.

[0067] Figure 6 is a side view of the gripper 32 and shows that the insert 62 has a front surface 66 that has a gripping profile that is a multi peaked or serrated profile. Figure 6 also shows that the peaks of the front surface 66 project proud of, or ahead of the front surface 58 of the body part 60. It follows, that when the grippers 32 are expanded into engagement with the facing surface of a drilled hole, the peaks of the insert 62 will generally engage the facing surface before the front surface 58 of the body part 60. The reason for this configuration will become evident from the discussion later herein.

[0068] Returning to Figures 1 and 2, the anchor 12 further includes the spring 36 and the tube 38. As shown in Figure 1, the spring 36 seats at the leading end against the bracket 34 and at the trailing end against the flange 68 of the tube 38. The leading end 70 of the tube 38 threadably connects to the trailing end 42 of the mandrel 30 and the spring 36 applies a bias to the bracket 34 tending to maintain contact between the bracket 34 and the trailing end 42 of the mandrel 30 and the spring load is distributed to the mandrel through the bracket 34. The spring 36 can be compressed during installation of the anchor 12 in a drilled hole to allow the bracket 34 to shift rearwardly and the grippers 32 to move towards the trailing end 42 of the mandrel 30 to reduce the radial dimension of the anchor 12. This allows the anchor 12 to continue passage

through a drilled hole where the diameter of the drilled hole is less than the radial dimension of the anchor 12 when the grippers 32 are in the initial position shown in Figure 1 as explained below.

[0069] A flanged sleeve 72 holds the grippers 32 in a retracted position prior to the anchor 12 being inserted into a drilled hole. The sleeve 72 is intended to catch at the opening of the hole and to slide off the anchor 12 as the anchor 12 is pushed into the hole. The flange 74 ensures that the sleeve 72 catches the opening of the hole. The sleeve 72 also protects the tips of the grippers 32 prior to installation.

[0070] During insertion of the rock bolt 10 into a hole, if the outer surface of the grippers 32 engages the facing surface of the hole, such as by scraping along the facing surface, the load applied to the grippers 32 can overcome the spring bias of the spring 36 allowing the bracket 34 to shift in the direction A (Figure 1), and allowing the grippers 32 to also shift in the direction A relative to the mandrel 30 along the taper of the mandrel 30 towards the trailing end 42. That movement of the grippers 32 reduces the outer diameter of the anchor 12 and thus shifts the outer surface of the grippers 32 away from the facing surface of the hole, facilitating continued insertion of the rock bolt 10 into the hole. It is also to be noted that the sawtooth profile of the front surface 58 of the body part 60 is inclined away from the direction of insertion of the anchor 12 into the hole so that the peaks of the profile do not bite into the facing surface of the hole if the front surface 58 scrapes against the facing surface of the hole. Likewise, the peaked profile of the insert 62 is also inclined away from the direction of insertion of the anchor 12 into the hole.

[0071] When the anchor 12 and the cable 14 have been pushed either to the inner end of the drilled hole, or to the desired position within the hole, the anchor can be activated. The drilled hole will be drilled to a diameter such that the outer faces of the grippers 32 will be in touching contact with the facing surface of the hole and that touching contact is assisted by the spring 36 urging the bracket 34 forward to shift the grippers 32 upwards along the wider part of the mandrel 30. That touching contact between the grippers 32 and the facing surface of the hole will usually be sufficient to be resistant to movement of the grippers 32 relative to the facing surface in the direction A so that when the anchor is activated, the grippers 32 will remain stationary relative to the facing surface while the mandrel 30 and the other anchor components connected to the mandrel 30, move in the direction A. Activation can be achieved by applying a pull load on the cable end 22, which causes the mandrel 30 to move in the direction A relative to the grippers 32 so that the grippers 32 travel up the taper of the mandrel 30 towards the leading end 40 and expand radially outwardly into more firm contact with the facing surface of the hole. As explained earlier herein, an initial pull load can be applied by the bolting equipment used to install the rock bolt into the hole. With the anchor 12 activated by this initial pull load and thus anchored within the hole, the cable 14 is also secured so that it can be severed at the open end of the hole, disengaging it from the bolting equipment. The bolting equipment can then move onto the next bolting location, and personnel and tensioning machinery can move into place to apply the rock plate assembly to the trailing end of the cable 14 and to then apply the operating or working tension to the cable 14. The load applied to the cable 14 can be set to reach a certain predetermined load before it is released, depending on the type of rock strata in which the rock bolt 10 is being installed.

[0072] It will be appreciated that in most cases, the initial touching engagement between the grippers 32 and the facing surface of the hole will be between the profile of the front surface 66 of the insert 62, given that, as shown in Figure 6, the peaks of the front surface 66 project proud of, or ahead of the front surface 58 of the body part 60. This is important where the anchor 12 is being expanded into engagement with a wall that is hard or very hard. With such a hard wall, the front surface 58 of the body part 60 may not be itself sufficiently hard to key, bite or expand into the wall surface, thus leaving frictional engagement only. However, the carbide inserts 62 of the grippers 32 have a hardness that ordinarily will exceed the compressive strength of the rock strata in which the anchor 12 is being installed and so expansion of the grippers 32 to bring the peaks of the front surface 66 of the inserts 62 into engagement with the facing surface of the hole can result in the peaked surface to change the facing surface, such as by keying, penetrating or breaking into the facing surface, causing it to crush, crumble or fracture. This crushing, crumbling or fracturing or pulverising of the facing surface of the hole allows the peaks of the inserts 62 to penetrate into the facing surface of the hole, gripping the facing surface. This penetration or purchase may be very minor or even close to negligible, but is greater than no penetration or purchase, which would be purely or solely frictional. Additionally, the crushing, crumbling or fracturing of the hole surface may not be confined to just in the area of the inserts 62, but the fracturing, crushing or crumbling might be broader beyond the boundaries of the inserts 62, even just slightly beyond the boundaries and if so, will allow the front surface 58 of the body part 60 to also bite into the facing surface. The grippers 32 thus obtain purchase in the fractured, crushed or crumbled section of the facing wall either by the grippers 32, or by a combination of the grippers 32 and the body parts 60, or by the body parts 60. In this latter situation, the grippers 32 can penetrate into the facing surface of the drilled hole, causing it to crush, crumble or fracture, but that effect on the facing surface may preclude the grippers 32 from applying a meaningful gripping load. In this situation, the front or gripping surface 58 of the body parts 60 will come into contact with the facing surface of the hole and it will be the body parts 60 of the grippers 32 that apply the gripping load required to securely anchor the anchor 12 within the

hole.

[0073] The grippers 32 are unique in relation to the use of the two separate materials of the body part 60 and the insert 62. In the illustrated embodiment, the body part 60 and the insert 62 can combine to grip the facing surface of the hole by the insert initially causing the facing surface to crush, crumble or fracture and then the body part 60 is able to more broadly engage the fractured facing surface, that it otherwise would not penetrate into because of the hardness of the rock. Without the inserts 62, the fracturing of the facing surface of the hole in hard rock on activation of the anchor 12 may not occur, thereby compromising the stability of the anchor 12 within the hole.

[0074] The use of the two separate materials of the body part 60 and the insert 62 is also unique in providing dual properties that the materials of the body part 60 and the insert 62 do not provide separately. As explained above, the use just of the body part 60 will not be sufficient to grip a hole wall where the rock strata is sufficiently hard. While the inserts 62 can be made of material that will facilitate gripping of a hard hole wall, manufacture of a gripper completely from a material such as carbide is not feasible because the gripper would likely be either too brittle, too expensive and/or too difficult to manufacture. Accordingly, the combination is a unique and beneficial solution.

[0075] However, it should be appreciated that the grippers 32 are just one form of gripper that falls within the scope of the present invention as explained earlier herein.

[0076] As an alternative, instead of the insert 62, the recess 64 of front surface 58 could be omitted so that the front surface 58 has an uninterrupted sawtooth profile. The front surface 58 could be coated either fully or partially with a hard coating, such as a carbide coating to form the gripper portion. An arrangement of this kind is shown in Figure 7, in which the gripper 76 has a body part 78 and a gripper portion 80, whereby the body part 78 is formed from steel, such as like the body part 60 of the earlier figures, and the gripper portion 80 is formed from carbide. The interface between the body part 78 and the gripper portion 80 is at the junction 82. The carbide gripper portion 80 has a front face 84 that has a sawtooth profile like the gripper 32 but there is no recess for receipt of an insert. Rather, the full front face of the gripper 76 is a carbide face. The gripper portion 80 can be fixed to the body part 78 in any suitable manner such as by brazing.

[0077] In alternative forms of the invention, the body part 78 could include a sawtooth profile, like the body part 60 of the gripper 32, but without a recess for receiving the insert 62, and the profile could be partly or fully coated with a suitable coating, such as a carbide coating. The coating could be applied for example, over a central section of the front face 84 (over the same surface area for example, as the front surface 66 of the insert 62 - see Figure 5) so that the coated area would be raised above the surrounding sawtooth profile, and the surrounding profile would remain a steel surface.

[0078] A further alternative is illustrated in Figure 8, in which a gripper 86 includes a body part 88 that has a front face 90 that is formed in a sawtooth profile. The body part 88 is a steel part. Three separate and spaced apart circular gripper portions 92 are fixed within circular recesses is formed within the front face 90 of the body part 88 and the front faces 94 of the gripper portions 92 are each formed with peaked profiles similar to the front surface 66 of the insert 62 of the previous figures. Figure 9 is a side view of the gripper 86 of Figure 8 and shows that the peaks of the profiles of the gripper portions 92 project above the sawtooth profile of the front face 90 of the body part 88.

[0079] Figures 7 to 9 illustrate different forms of the invention from those illustrated in Figures 1 to 6 that all fall within the scope of the present invention.

[0080] Where any or all of the terms "comprise", "comprises", "comprised" or "comprising" are used in this specification (including the claims) they are to be interpreted as specifying the presence of the stated features, integers, steps or components, but not precluding the presence of one or more other features, integers, steps or components.

[0081] Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is understood that the invention includes all such variations and modifications which fall within the spirit and scope of the present invention.

[0082] Future patent applications may be filed claiming priority from the present application. It is to be understood that the following claims are provided by way of example only, and are not intended to limit the scope of what may be claimed in any such future application. Features may be added to or omitted from the claims at a later date so as to further define or re-define the invention or inventions.

Claims

1. An anchor (12) for a rock bolt (10), the anchor (12) being connectable to a cable or rod (14) and being expandable between a hole insertion condition and a hole anchor condition, the anchor (12) having:

   at least one gripper (32) that is expandable outwardly from the insertion condition of the anchor (12) to the anchor condition of the anchor (12) for gripping the facing surface of a hole in which the anchor (12) is installed,
   the gripper (32) comprising a body part (60) and a gripper portion (62), the body part (60) being formed from a hard material, the gripper portion (62) being formed of a material having a greater hardness than the body part (60), the gripper portion (62) having an outer facing gripping surface (66) that projects beyond the body part (60) in the direction of outward expansion of the

gripper (32).

2. An anchor (12) according to claim 1, the body part (60) having a recess (64) and the gripper portion (62) being an insert fixed within the recess (64).

3. An anchor (12) according to claim 2, the recess (64) being generally central of the body part gripping surface (58).

4. An anchor (12) according to any one of claims 1 to 3, the recess (64) having a base and a peripheral wall upstanding from the base and the insert (62) being supported on the base within the peripheral wall.

5. An anchor (12) according to claim 4, the insert (62) having a leading end and a trailing end and side walls extending between the leading and trailing ends, the leading and trailing ends being aligned generally with the axis of insertion of the anchor (12) into a hole in which the anchor (12) is to be installed, the peripheral wall being a close fit about at least the leading end and the side walls of the insert (62).

6. An anchor (12) according to claim 1 or 2, the gripper portion (32) being formed of two or more gripper portion units (92).

7. An anchor (12) according to claim 6, the gripper portion units (92) each being located in a recess in the body part (88).

8. An anchor (12) according to claim 7, the gripper portion units (92) being circular and being inserted into circular recesses, such as by brazing or friction fit.

9. An anchor (12) according to claim 1, the body part (88) having an outer facing gripping surface (90) and the gripper portion (92) being connected to the body part (88) so that the outer facing gripping surface (94) of the gripper portion (92) projects from the body part gripping surface (90).

10. An anchor (12) according to claim 9, the body part gripping surface (90) having a different gripping profile to the gripper portion gripping surface (94).

11. An anchor (12) according to claim 10, the gripper portion gripping surface (94) having a multi peaked or serrated profile formed from multiple projections whereby distal ends or apexes of the projections project from the body part gripping surface (90).

12. An anchor (12) according to claim 10 or 11, the body part gripping surface (90) having a sawtooth profile.

13. An anchor (12) according to any one of claims 1 to 12, the body part (60) being made of steel and the gripper portion (32) being made of tungsten carbide.

14. An anchor (12) according to any one of claims 1 to 13, the anchor (12) having a leading end and a trailing end and at least one gripper (32) being moveably mounted to a tapered mandrel (30) whereby the mandrel (30) has a smaller diameter trailing end (42) and larger diameter leading end (40), expansion of the gripper (32) is by movement of the mandrel (30) relative to the gripper (32) so that the gripper (32) shifts on the mandrel (30) in a direction towards the leading end (40) of the mandrel (30).

15. An anchor (12) according to claim 14, the gripper (32) being moveably mounted to the mandrel (30) by a sliding keyed arrangement (54,56) and the gripper (32) having an installation position relative to the mandrel (30) and an expanded condition, at least in the installation position, the gripper (32) is in engagement with a movable abutment (52).

Fig 1

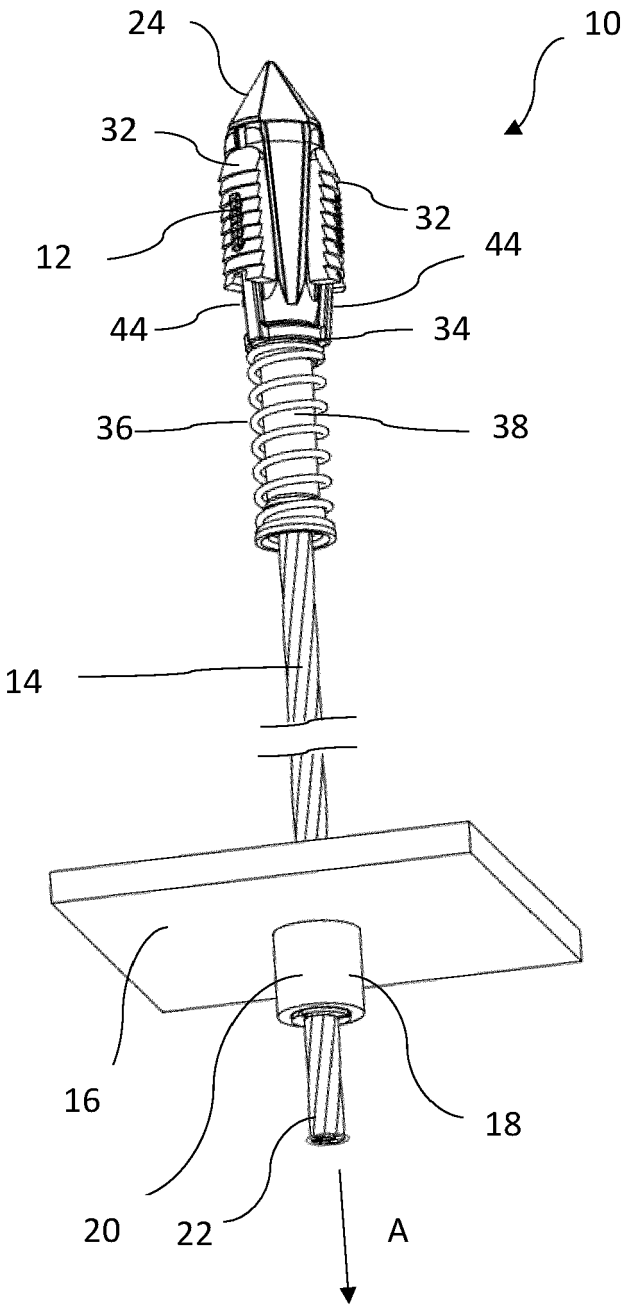


Fig 2

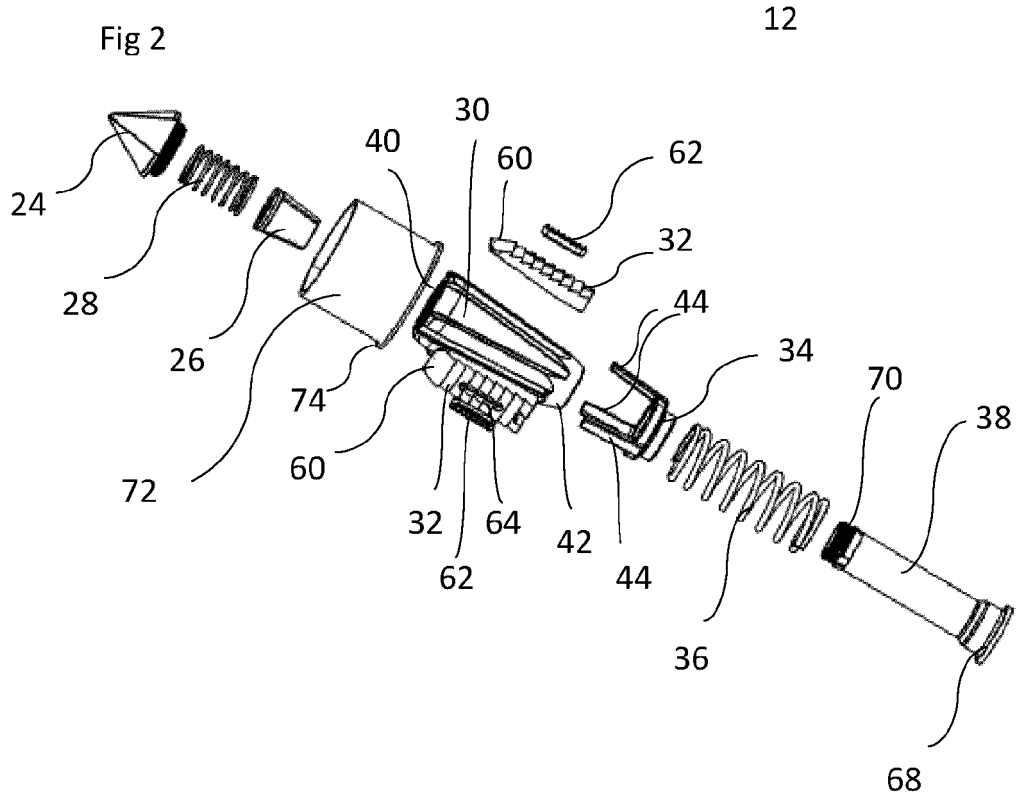


Fig 3

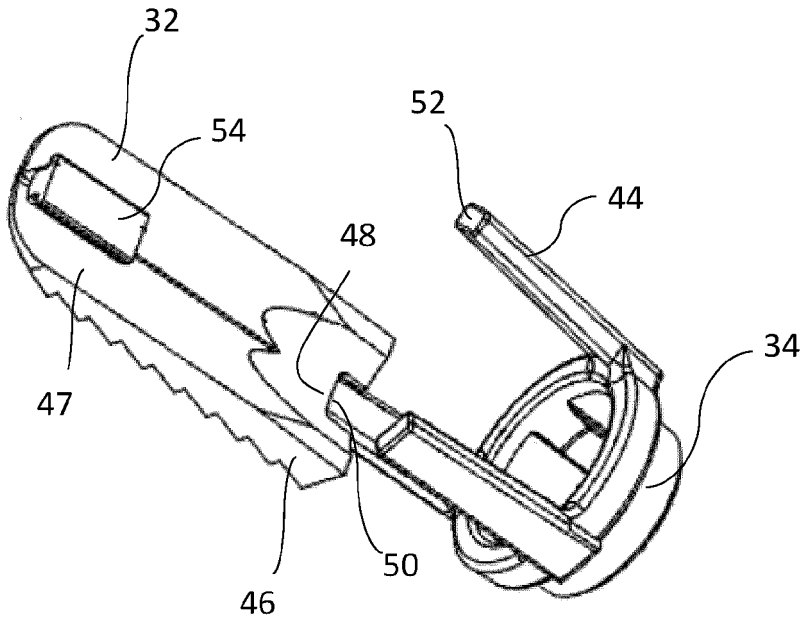


Fig 4

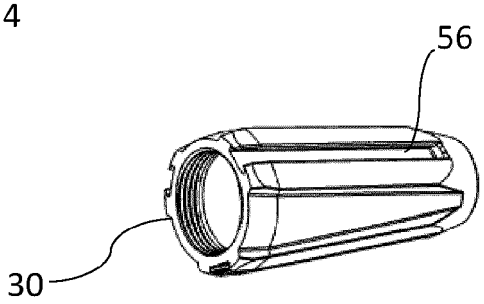


Fig 5

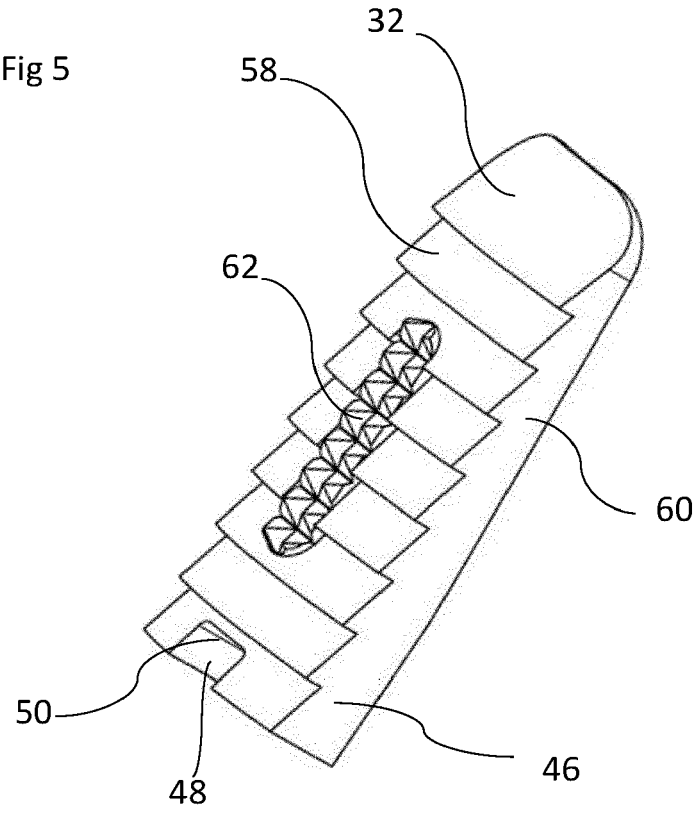


Fig 6

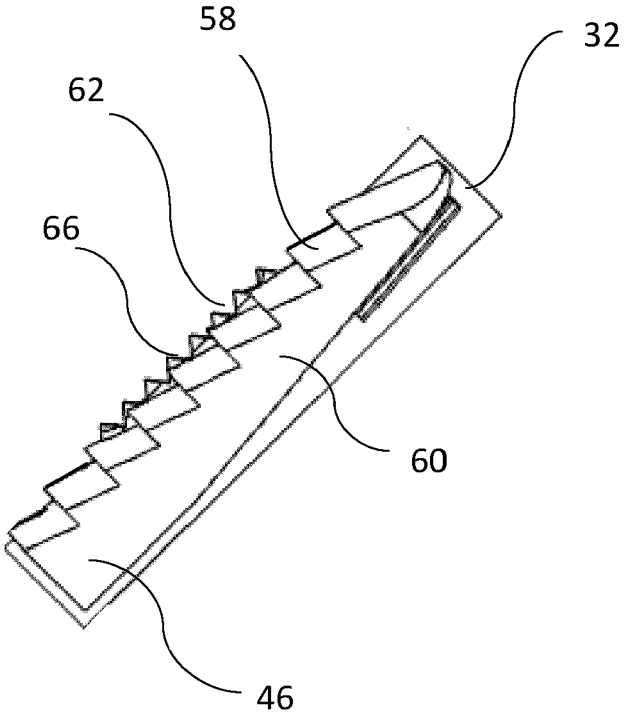


Fig 7

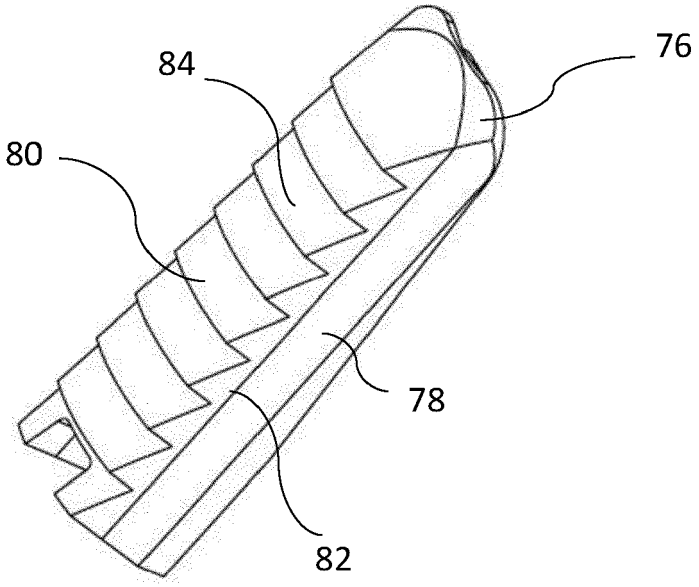


Fig 8

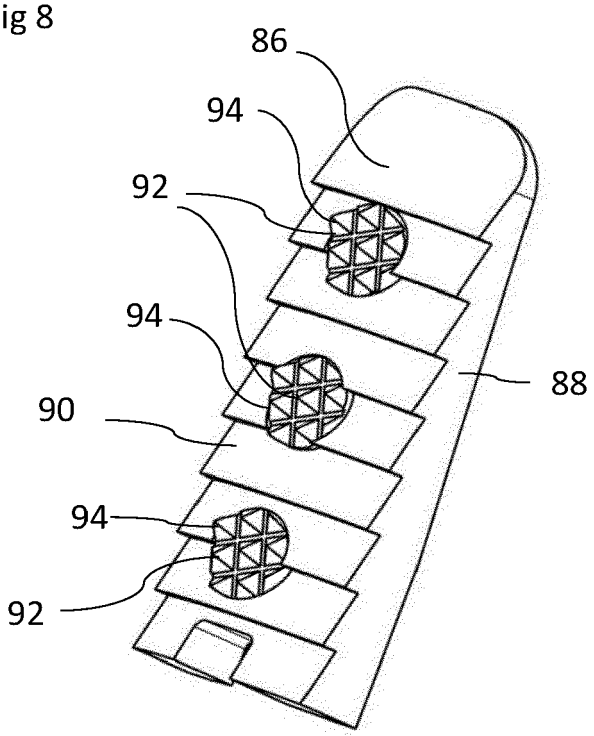
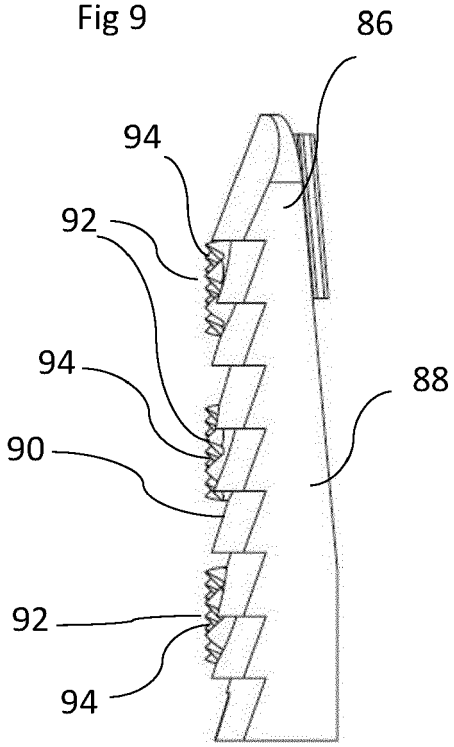


Fig 9



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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 7244

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CN 211 852 435 U (MKT TECH BEIJING CO LTD) 3 November 2020 (2020-11-03) * the whole document *	1-7, 13-15	INV. E21D21/00
X,D	EP 0 068 227 A1 (UPAT MAX LANGENSIEPEN KG [DE]) 5 January 1983 (1983-01-05) * page 6, line 1 - page 9, line 29; figures 1-6 *	1-3,6-8, 13-15	
X	GB 2 284 032 A (LONGLEYS [GB]) 24 May 1995 (1995-05-24) * page 7, line 4 - page 9, line 31; figures 1-4 *	1-10,12	
X	US 3 577 825 A (REUSSER HANS E) 4 May 1971 (1971-05-04) * column 2, line 48 - line 71 * * column 6, line 23 - column 7, line 37; figures 1-5a *	1,6,14, 15	
X	GB 2 262 147 A (WILLICH F BERG BAUTECHNIK [DE]) 9 June 1993 (1993-06-09) * page 9, paragraph 2 - page 10, paragraph 1 * * page 12, line 11 - page 17, line 20; figures 1, 3 *	1,6,9	TECHNICAL FIELDS SEARCHED (IPC) E21D F16B
A	CN 114 439 523 A (HANGZHOU TOUQIANG ENGINEERING MAT LIMITED COMPANY) 6 May 2022 (2022-05-06) * the whole document *	1-15	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	22 March 2024	Jucker, Chava

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 20 7244

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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22-03-2024

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **POTVIN** ; **HADJIGEORGIOU**. Ground Support for underground mines. *Australian Center for Geomechanics*, 2020, ISBN 978-0-9876389-5-3, 8 **[0013]**