United States Patent

Williams

[15] **3,653,217**

[45] **Apr. 4, 1972**

[54] ROCK BOLT ROD CONFIGURATION

[72] Inventor: **Chester I. Williams,** 347 Greenbrier, S.E., Grand Rapids, Mich. 49506

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 12,221, Feb. 18, 1970.

[52] **U.S. Cl.** ..... **61/45 B,** 52/698

[51] **Int. Cl.** **E21d 20/02**

[58] **Field of Search** ..... 61/45 B; 52/698, 704, 707, 52/156, 166; 85/20, 21, 63

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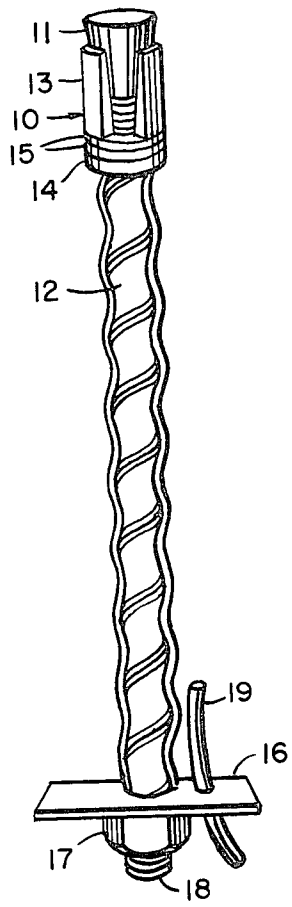
Primary Examiner—Dennis L. Taylor
Attorney—Glenn B. Morse

[57] **ABSTRACT**

A surface configuration for a rock bolt rod defined by one or more indentations arranged generally transversely with respect to the axis of the rod, and having a maximum slope of 15° with respect to the axis of the bolt rod on the side of the indentation most remote from the surface plate of the rock bolt assembly.

10 Claims, 8 Drawing Figures



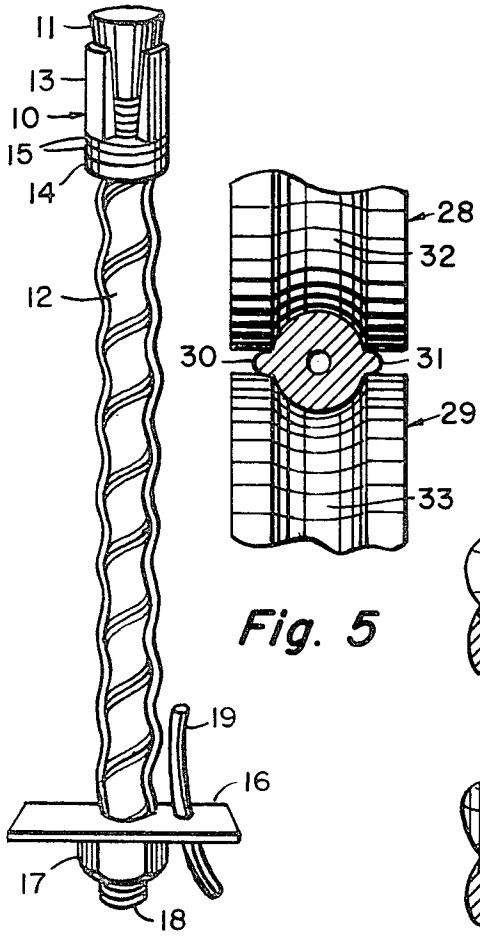


Fig. 1

Fig. 5

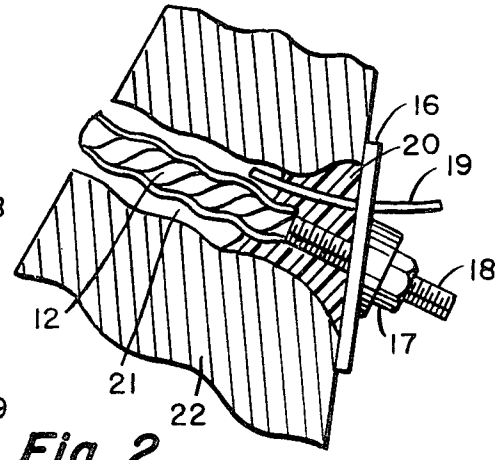


Fig. 2

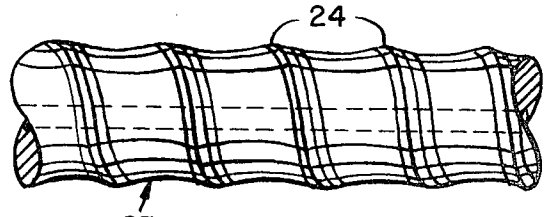


Fig. 3

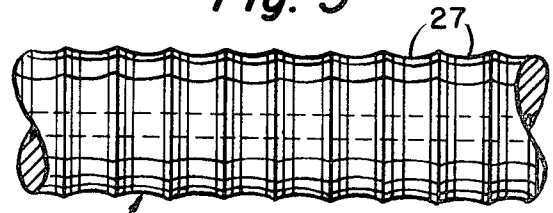


Fig. 4

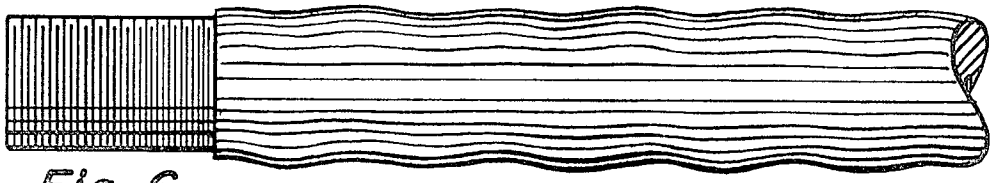


Fig. 6

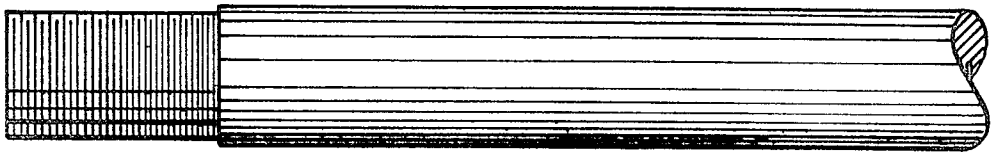


Fig. 7

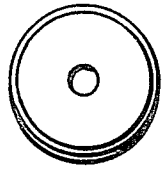


Fig. 8

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ROCK BOLT ROD CONFIGURATION

CROSS-REFERENCE

This application is a continuation-in-part of my application, Ser. No. 12,221, filed in the U.S. Pat. Off. on Feb. 18, 1970.

BACKGROUND OF THE INVENTION

Rock bolts are commonly used to secure a ground formation in the neighborhood of constructions projects. These bolts are installed in long holes drilled into rock, with the inner end of the rock bolt assembly usually being provided with some form of an anchoring device. The rod extends from this point to the surface assembly, which usually includes a heavy bearing plate placed across the entrance of the hole, to which forces are transferred from the bolt through a conventional nut in threaded engagement with the bolt rod. These rock bolts will commonly run to 60 feet in length. It is standard practice to inject grout into the hole around the rock bolt to establish a bond between the bolt rod and the surrounding rock, and to provide a protective sheath around the rod. Grout is a cementitious material in initially liquid form, and is preferably injected into the hole around the bolt rod after the anchoring device has set. This is done preferably after a substantial degree of pre-stress condition has been applied to the bolt rod, as discussed and claimed in my co-pending application, application Ser. No. 8,345 filed on Feb. 3, 1970.

Grout will exhibit a very strong adhesion to an uncoated steel bolt rod, and this adhesion characteristic is utilized by engineers in calculating the necessary rock bolt installations required for a particular ground condition. Once the rock bolt has been installed in the hole, the anchor set, and the desired pre-stress developed, it is preferable that the entire length of the rod be bonded as intimately as possible to the surrounding rock along the full length of the rod. An exception to this situation will exist in cases where a subsequent tightening of the rock bolt may be necessary as a result of shifting of the surface area of the rock formation as a result of blasting conditions or other movement. The adhesive bonding of the grout to a conventional rock bolt rod determines the maximum transfer of forces per unit of length along the rod, as it is obvious that the pull-out resistance of this bonding action is defined by the shear strength of the grout on a plane immediately adjacent the surface of a cylindrical bolt rod, or by the intensity of the adhesive bond, whichever is the lesser.

It is obvious that any coating of grease, oil, or other foreign substance on the surface of a cylindrical bolt rod will impair or eliminate the adhesion of the grout, and thus correspondingly influence the bonding action. It is customary to at least expose steel parts to oily material of one kind or another during the process of manufacture, and the risk of impairing the bond of the grout to the rod has been eliminated largely by the use of various forms of corrugation on the surface of the rod. These corrugations are also commonly found on rods used for reinforcing concrete structures. The corrugations are usually defined by patterns of protrusions on the surface of the rod that are essentially rectangular or semi-circular in cross section on a plane containing the axis of the bolt rod. These protrusions produce a degree of interengagement with the surrounding grout, such that the setting of the grout will provide some degree of mechanical interlock with the bolt rod to supplement the adhesive bonding. This positive interlock assures that the pull-out resistance of the rock bolt in the grout will at least be equal to the shear strength of the circumscribed cylinder around the bolt rod in the grout material. With this sort of positive interlock between the bolt and the grout, it is obvious that the rod cannot be stretched with respect to the surrounding rock formation, and is thus unable to adjust itself to changes in stress conditions after the initial installation of the rock bolt.

SUMMARY OF THE INVENTION

Applicant has determined that the performance of a rock bolt rod can be improved in several respects by providing the surface of the rod with a pattern of transverse indentations having a very small maximum slope in cross section, as viewed upon a plane containing the axis of the bolt rod. This slope relationship causes the surface of the rod to function in the manner of a wedge, rather than in solid mechanical interlock with the surrounding grout. In cases where the rod becomes capable of slight movement with respect to the grout, such movement instantly generates tremendous pressure forces in a generally conical configuration, placing the grout in heavy compression between the bolt rod and the rock formation. These forces are distinctly different from shear forces developed on the circumscribed plane in the grout around the bolt rod. Even it it be considered that the grout is subject to shear along this circumscribed cylindrical plane, the presence of these immense pressure forces extending outward from the bolt rod will establish a degree of friction on this plane which will exceed the normal shear stress of the grout.

It is preferable that the indentations be symmetrical in cross section, although a saw-tooth configuration can be incorporated where it can be assumed that all of the stress is in a particular direction. It is significant here that such a saw-tooth arrangement be oriented in such a way that the loading is applied against the gradually-sloped face, rather than against the steeper slope. It has been common practice in the design of rock bolt anchors and in devices inserted in concrete to utilize a reverse of this arrangement, in which the pull-out forces become defined as the shear strength of the grout on the circumscribed plane immediately adjacent the rod. The symmetrical indentations have the additional advantage of presenting less interference with grout flow along the rod.

The preferred pattern of the indentations is defined as a helical or undulated arrangement occupying the entire outer surface of the rod. As an alternative, an annular pattern can be used involving a series of similar indentations. These indentations are preferably established by a cold working action which leaves the material of the rod at the indentations more severly cold worked (and thus consequently stronger) than the material immediately underneath the surface area. When the helical pattern is used, the configuration may be applied by a process analogous to thread-rolling. As an alternative, the configuration may be applied by a steel mill by passing the rod stock between rollers. This latter technique will normally result in a pair of diametrically opposite ridges along the full length of the rod intersecting whatever pattern has been established in an annular or helical arrangement around the rest of the rod. These axial ridges, since they are not transverse, do not interfere with the functioning of the remainder of the periphery in the grout. Where the undulated arrangement is used (with the axis of the rod following a serpentine path in essentially one plane), the configuration may be applied either in the hot-rolling process in which the rod material is initially manufactured, or may be imparted as a secondary operation by placing the rod elements between suitably formed dies installed in a heavy press. Since the most effective forms of rock bolts involve hollow interiors to provide for the passage of grout, it is desirable that this interior bore remain as close as possible to a straight line. This provision not only assures a minimum interference with grout flow, but also a minimum interference with the removal of the usual non-ferrous core material incorporated in the original ingot processed into the rod configuration. The rod only becomes tubular after the removal of this central core material, which is rendered somewhat difficult if the core material has deviated much from a straight line. Where the desired exterior rod configuration cannot be practically produced without excessive deviation of the core, secondary operations become necessary.

DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view showing a rock bolt assembly including a bolt rod provided with a configuration embodying the present invention.

FIG. 2 illustrates the surface portion of a rock bolt assembly installed in a rock formation.

FIG. 3 is a view on an enlarged scale of a portion of a bolt rod embodying one form of the present invention, on an enlarged scale over FIGS. 1 and 2.

FIG. 4 illustrates a modified form of the invention on the approximate scale of that of FIG. 3.

FIG. 5 illustrates the method of manufacture of the form of the invention incorporated in FIGS. 1 and 2.

FIG. 6 is a side elevation of an undulated rock bolt rod, in which the axis of the rod remains substantially in one plane.

FIG. 7 is a plan view of the rod shown in FIG. 6.

FIG. 8 is an end view of the rod shown in FIGS. 6 and 7.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The rock bolt assembly illustrated in FIG. 1 includes an anchoring device generally indicated at **10**. The components of this device include the cone **11** in threaded engagement with the bolt rod **12**, the expansible shell **13**, the thrust ring **14** in threaded engagement with the bolt rod **12**, and the slip rings **15** which function as a thrust bearing between the end of the shell **13** and the thrust ring **14**.

At the outer end of the rock bolt assembly, the bolt rod **12** traverses the surface plate **16**, to which the bolt rod forces are transferred by the convential nut **17** engaging the threaded end **18**. A plastic tube **19** extends through a small opening in the plate **16** to provide a passage for the exhaust of air, or for the injection of grout, depending upon the orientation of the axis of the rock bolt installation with respect to the horizontal. FIG. **2** illustrates the condition of the surface components of the rock bolt assembly in condition preparatory to the grouting operation. A quantity of mastic material **20** is packed around the bolt rod **12** where it emerges from the hole **21** in the rock formation **22**. The bolt rod **12** is hollow, and the installation shown in severely **2** will be grouted by the injection of grout in the tube **19**. As the grout progressively fills the hole, air will be exhausted through the hollow interior of the rod **12**. This grouting procedure is preferably done under sufficient pressure to drive the grout in its initially liquid condition into intimate contact with the rod throughout the length of diametrically-opposite rock bolt installation, and into solid contact and interengagement with the irregularities of the rock formation defining the hole **21**.

In the form of the invention illustrated in FIG. **3**, the rod **23** is provided with a continuous annular depression producing the ridge **24** and the valley **25**. It is significant that the surface of the indentation or depression has a slope adjacent the ridge **24** of less than 15° with respect to the axis of the rod **23**. The form of the invention illustrated in FIG. **3** involves an indentation pattern which is symmetrical at the opposite ends (or on either side of the ridge **24**), which makes it possible for the bolt rod to transfer stresses to the rock formation in opposite directions along the length of the rod. Where a surface portion is being held in restraint by forces at the inner extremities of the rod, it is obvious that this opposition of forces will inevitably be involved. In FIG. **4**, essentially the same result is provided on a bolt rod **26** through the provision of a series of annular indentations **27** having the same general shape as that illustrated in FIG. **3**. The helical indentation in FIG. **3** can be performed by a process similar to thread rolling, and that in FIG. **4** by a sequence of rolling operations accompanied by the repeated indexing of the rod through the rolling machine. Either of these procedures will result in applying a degree of cold work to the material of the rod adjacent the indentations which will strengthen the rod to a degree to offset the reduction in cross section at the base of the indentations. It is significant that the helical configuration has a constant cross section along its length, while the repeated indentations in FIG. **4** will exhibit changes in cross section between points at the valleys and those at the peaks of the indentations. The reduction in cross section is offset considerably by the increase strength resulting from the cold work condition of the material at the indentations.

FIG. **5** illustrates the method of manufacture of the configuration shown in FIG. **1**. The helical pattern in incorporated in rolls **28** and **29**, which are spaced sufficiently to provide for the formation of the axial ridges **30** and **31** as material is squeezed out between the rolls. The formed surfaces **32** and **33** of the rolls are prepared in such a way as to produce a configuration similar to that shown in FIG. **3**, with the addition of the axial ridges **30** and **31**.

The rod configuration illustrated in FIGS. **6**, **7**, and **8** is a wave-like pattern in which the deviations are in essentially one plane. Assuming that the axis of the rod is considered as the transverse center between the opposite extremities of the surface shown in FIG. **6**, the axis will have a strictly two-dimensional wave pattern, rather than the helix arrangement illustrated in FIG. **1**. With FIG. **6** considered as a side elevation, this configuration obviously results in the rod appearing as having parallel sides in plan. FIG. **8**, being a view from the left end of FIG. **7**, further illustrates this arrangement.

While the relationships of the maximum slope of the periphery of the rod with respect to a straight line tangent to the side of the rod remain as previously described, it must be noted that an undulation pattern having short pitch can be imparted to the rod with a minimum tendency to distort the central grout passage. It has been found that the following relationships between the rod diameter, the pitch of the undulations (which are preferable symmetrical), and the depth of the undulations will produce a rod of superior holding characteristics as previously described, and produce a minimum tendency for distortion of the central grout passage either in the case where the final undulated configuration is incorporated in the hot-rolling process, or as a secondary operation:

Rod diameter	Pitch of the Undulations	Depth of the undulations from trough to crest
1"	1"	0.070"
1⅜"	1⅜"	0.101"
2"	2"	0.115"
3"	3"	0.173"

All of the configurations illustrated in the drawing will exhibit the same tendency to generate tremendous pressure forces radiating outward into the rock formation through the grout on generally conical patterns whenever there can be sufficient relative slippage or shear deflexion adjacent the surface of the bolt rod to permit a wedging action to develop.

The superiority of this retention by radial pressure, as opposed to mere adhesion or interlock, invites the development of this action by the intentional application of lubricant to the rod surface. With the lubricant it appears that the maximum angle of slope of the depressions is 15°. For best results, the angle should be close to 10°. Preliminary investigation suggests that smaller slopes are to be recommended where grout adhesion can be expected to prevent freedom of impending slippage necessary to develop the wedging action. The axial length of the depressions results from a compromise between the reduction in rod diameter (with the larger indentations) and a desirable length of the incline. Good results appear to follow the use of arcuate depressions of one-quarter to one-half the rod diameter in axial length and one-sixteenth to one-thirtysecond of the rod diameter in depth.

I claim:

1. In combination with a mass of grout placed in a hole in a ground formation, a rock bolt including a surface plate, a nut normally bearing against said plate, a rod engaging said nut and installed in said hole, and an anchor device at the inner extremity of said rod, said rod being surrounded by said grout initially in the liquid condition thereof, wherein the improvement comprises:

means forming a peripheral surface on said rod defined by repeated cycles of at least one transverse indentation which creates a wedging action between the rod and the surrounding grout and having a maximum slope with respect to the axis of said rod, at least on the side of said indentation most remote from said surface plate, of less than 15°.

2. A combination as defined in claim **1**, wherein said indentation is annular.

3. A combination as defined in claim 2, wherein substantially all of the surface of said rod is defined by a series of said indentations.

4. A combination as defined in claim 1, wherein said indentation is helical.

5. A combination as defined in claim 4, wherein substantially all of the surface of said rod is defined by at least one of said helical indentations.

6. A combination as defined in claim 1, wherein the material of said rod at said indentations is more severely cold-worked than the interior of said rod.

7. A combination as defined in claim 1, wherein said rod is coated with a material preventing adhesive bonding to said grout.

8. A combination as defined in claim 1, wherein said indentation is substantially symmetrical in a cross-section on a plane parallel to the axis of said rod.

9. A combination as defined in claim 1, wherein said rod has a pattern of transverse indentations in the form of an undulation wherein the axis of said rod remains substantially coplanar co-planar.

10. A combination as defined in claim 9, wherein the pitch of said undulations is less than 1 ½ times the diameter of said rod, and the full depth of said undulations from trough to crest is less than one-tenth of the rod diameter.

* * * * *