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(54) Method and apparatus for fracturing rock.

(57) A method of fracturing rock includes the steps of drilling a hole into the rock required to be fractured, modifying the shape of the hole, and rapidly pressurizing the modified hole to initiate and propagate cracking to a free surface of the rock. Apparatus for accomplishing the method includes two variations of apparatus for allowing very rapid injection of a pressurized liquid into a hole.

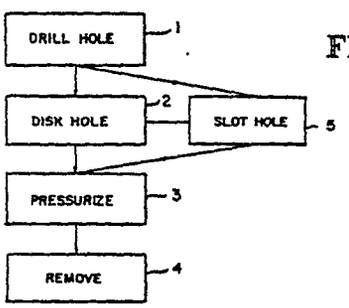

FIG. 1

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"Method and Apparatus for Fracturing Rock"

This invention pertains to fracturing rock, particularly to the fracturing of rock from a headwall as in tunnelling, and with greater particularity to the fracturing of rock from a headwall without the use of chemical explosives.

Conventional mining and tunnelling is usually accomplished by first drilling a number of holes in the rock face to be tunnelled into. The holes may or may not be drilled according to a predetermined pattern. Chemical explosives are then placed in the holes and detonated in a predetermined or random manner dependent upon application. When the explosives detonate, the rock is shattered. The shattered rock is then removed and the operation repeated. The safety and pollution disadvantages of this method are well known. These disadvantages have led to the proposal to use mechanical mining means. Known machines include shield machines and mechanical boring devices. To date, however, such devices have not been successfully used in many circumstances due to their high cost.

An additional method has been proposed in which a hole is drilled into the rock face. A series of notches are then cut normal to the hole either by use of a mechanical cutter or by use of a high pressure water jet directed normal to, or at a slight angle to, the hole. The slot thus formed is then used as a crack initiator when a force is applied to the rock on either side of the slot. In

a variation of the above method, it has been proposed to seal the hole at either side of the slot and pressurize the slot with water forced through the nozzles of the water jet used to cut the slots. To date none of the above methods have found widespread commercial application due to the large amount of force required to fracture rock that must be exerted with mechanical means in hard rock, or the absorption of the pressurizing water due to rock permeability and pre-existing cracks.

It is an object of the present invention to provide an economical and safe method for a single operator to tunnel into rock faces. The method uses no explosives or dangerous chemicals.

The method comprises the steps of first drilling a hole by water jet or convenional means. A slot is then cut from the hole. The slot removes an approximately disc shaped section of rock. The slot is then rapidly pressurized in a semi-explosive manner from a reservoir of pressurized liquid. The result is an outward force on the rock of several tens of thousands of kilograms. The resulting force is sufficient to fracture the rock to the surface of the rock face. The fractured section will then either fall of its own accord, or may be easily removed.

Apparatus of the invention includes a rock drilling device that may be modified to include a hole slotting tool. The apparatus further includes means for pressurizing the slotted hole in a short time. Finally, the apparatus includes safety systems to prevent possibility of harm to an operator.

The method of the invention may also be used to split rock already quarried. A hole is first drilled into the rock to be split. A slot is next cut from the hole in the direction in which the split is required. The hole and the slot are then pressurized suddenly with a high pressure liquid to initiate cracking along the slot. The rock is thus split by the quick pressurization.

The invention will now be described by way of example, with reference to the drawings, in which:-

Figure 1 is a block diagram showing the method of the invention;

Figure 2 is a diagram showing the apparatus of the invention;

Figure 3 is a sectional view of a packer used in the apparatus; and

Figure 4 is a sectional view partly in elevation of a second packer used in the apparatus.

Referring to Figure 1, first a hole is drilled 1 into the rock sought to be fractured. The drilling may be accomplished by a conventional rock drill, that is electrically, hydraulically, or pneumatically powered. Alternatively, the hole may be made by a water jet drill. The depth of the hole drilled is dependent upon the application and the crack characteristic required. A typical hole diameter is from 15.87 to 44.45 mm. Hole depths of from 23 to 122 cms. have been successfully used. Second, a disc is cut 2 near the bottom of the drilled hole. The disc may be perpendicular to the hole, or at an angle to the hole ranging from 30 to 150°, producing a

forward or reverse disc cavity. The disc may be cut by a tool intended for the purpose such as a rotatable high pressure water jet, or the drill itself if it is a water jet drill as referred to above. The disc may be cut with a mechanical cutter. The purpose of the disc is to create a stress riser or notch condition to aid initiation of cracking and to control the initial direction of cracking. By selection of the angle of the disc, the direction of cracking initiation can be controlled. If the disc is placed in an unconfined rock of a diameter measured in the plane of the disc equal to less than four times the depth of the drilled hole, a crack will propagate in the plane of the disc until it reaches a free surface normal to the plane of the disc at a diameter of about 8 times the hole depth. If the hole is placed in massive rock, or a rock face, the crack will propagate in the plane of the disc for a radial distance approximately equal to the depth of the drilled hole, then curve to the free rock face. The disc should be cut as close as possible to the end of the hole. If the disc is not close to the end of the hole, crack initiation can begin at the hole end which will interfere with the desired crack geometry. The disc cut can vary in diameter from relatively small, i.e. from 190 mm. to several cms. The large diameter disc takes longer to cut, but allows greater concentration of stress.

Once the hole has been made disc-shaped, it is pressurized 3 to initiate cracking. It has been

found desirable to pressurize the hole at a rapid rate. Pressurization is accomplished by rapid injection of a liquid, for example water, into the disc. Sufficient liquid must be injected to both fill the hole and the resulting crack. If the liquid is not injected fast enough, the initial liquid will be absorbed into the pores of a porous rock such as sandstone. If the liquid is absorbed, there will not be a sufficient force gradient at the disc to initiate cracking. Prior proposals have not recognized this factor and have been tested in non-porous materials in which the absorbtion is not observed. If a rock such as sandstone is slowly pressurized to a pressure as high as 2465 kg cm^2 fracturing will not occur. If, however, the pressurization is sufficiently rapid, fracturing will occur with pressures as low as 7 kg. cm^2. A desirable time for injection of liquid sufficient to fill the disc is less than 1/50th of a second. In addition, sufficient liquid must be injected to fill the crack as it propagates or else cracking will stop. A typical requirement of liquid capacity is at least one litre. Prior proposals which include pressurization through water cutting jet orifices pressurized from a hydraulic intensifier cannot reach the required flow rates, so alternative pressurization methods must be used. One method is to pressurize a hydraulic accumulator having sufficient liquid capacity and filled with a gas, for example nitrogen. This produces a source of high pressure liquid of sufficient volume and flow rate. A tube is then

connected to the accumulator with a quick opening valve and sealed to the hole with a quick setting cement or grout. When the valve is opened, the result is analogous to ignition of a low explosive, such as black powder, in the disc portion of the hole. Such an explosion initiates cracking rather than shattering (as compared with a high explosive such as nitroglycerine). This is commonly called a heaving action. Further injection of liquid continues the cracking until the crack reaches a free surface causing loss of pressure. The liquid can also be injected by a special packer tool to eliminate the time required for the grout to harden. The injection point from the packer must be close to the disc to minimize the possibility of crack propagation from the hole.

When the crack propagation is finished, the result will be a cone-shaped fragment of rock cracked away from the face. Generally, the fragment will not fall free from the face, but can be easily detached by inserting a small chisel into the crack. This allows easy removal 4 of the fragment. The method is then continued to drill a tunnel.

Alternatively, the drilled hole may be slotted 5. Slotting can create two slots perpendicular and coplanar to the hole. The slotting may be accomplished by use of a water jet cutter being moved through the hole, or a mechanical slotting device. When the slot is pressurized 3, as described above, cracking is initiated in the plane of the slots.

Such a crack will extend until it encounters a free face. This slotting method allows fracture of detached boulders. This cracking can be used on a face alone or in combination with the disc hole method to allow detachment of large blocks and establishment of a tunnel perimeter.

Referring to Figure 2, a hydraulic intensifier water pump 11 powers the apparatus of the invention. Pump 11 may be an intensifier of the type commonly used for water jet cutting. A selector valve 12 is connected to the output of pump 11. A water jet disc tool 13 is connected to one output of valve 12. Tool 13 may be a tool designed exclusively for cutting disc holes. The other output of selector valve 12 is connected to a gas/water accumulator 14. Accumulator 14 may be any accumulator having sufficient pressure and volume capabilities with a bladder type N_2 accumulator having a capacity of 4.5 litres charged to 210 kg cm^2 being used in initial tests. The inlet of a rapid opening valve 16 is connected to accumulator 14. A rapid opening ball type valve with piezo electric monitoring capability was used in initial tests. The outlet of valve 16 is connected to a packer 17 inserted into a hole 18 having a cut disc 19.

To operate the system, pump 11 is started and selector valve 12 adjusted to provide high pressure water to tool 13. A hole is then drilled into the rock face 21. The hole is then made disc-shaped by tool 13, creating a disc 19 at the end of hole 18.

Selector valve 12 is then adjusted to pump up accumulator 14. Packer 17 is inserted into hole 18. Valve 16 is opened causing liquid to flow rapidly through packer 17 and pressurize disc 19 causing formation of a crack 22 running to rock face 21. A chisel is inserted into crack 22 allowing removal of the cone-shaped block 23 from the remainder of the rock 24.

Referring to Figure 3, a packer is shown inserted into a disc hole. A supply tube 31 has a connector 32 for attachment to a supply of high pressure liquid. Supply tube 31 includes a tapered end 33 opposite connector 32. External threads 34 are provided on the surface of supply tube 31 adjacent to connector 32. An anchor tube 36 having an internally threaded section 37 is threadedly connected to supply tube 31. Two anchors 38, 39 are pivotally connected to the end of tube 36 opposite threaded section 37 by a pin 41. Anchors 38 and 39 are retained in position by a spring 42 connected between them. A slot 43 is provided in anchor tube 36. The packer is shown inserted into a hole 44 with a slot 46 and a step 47. Slot 46 and step 47 may be cut with a water jet or a mechanical cutter. In operation the packer is inserted into hole 44 and anchor tube 37 rotated relative to supply tube 31. This causes a bevelled surface 33 of supply tube 31 to contact and force apart anchors 38 and 39 which catch on step 47. Supply tube 31 is pressurized through connector 32 to crack the rock from slot 46.

The diameter of anchor tube 36 is chosen to match that of hole 44 sufficiently closely so that it almost seals it, due to the relatively great length of hole 44 and the small clearance between tube 36 and hole 44. The cross sectional area of the clearance between hole 44 and tube 36 must be less than the cross sectional area of the interior of supply tube 32 to enable disc 46 to be rapidly pressurized to initiate cracking before substantial leakage has occurred. Anchors 38, 39 are necessitated by the outward force exerted upon the packer when hole 44 is pressurized and prevents it from being blown out of hole 44. After fracturing, tube 36 is again rotated relative to supply tube 31 allowing spring 42 to retract anchors 38, 39 so that the packer may easily be withdrawn from hole 44.

Referring to Figure 4, a second packer includes an alloy steel supply tube 51 having a connector 52 for attachment to a supply of high pressure liquid at one end and a section of tapered threads 53 at the other end. A short alloy steel tube 54 which can be formed into three pieces has a tapered threaded section 56 and is threadedly attached to tube 51. Three slots 57 are thus formed out of tube 54 and additionally grooves 58 are cut into the outer surface of tube 54. A seal 59 is threadedly attached to supply tube 51 and slidably connected to tube 54. Supply tube 51 is inserted into a drilled hole and rotated relative to tube 54. This causes the sections of tube 54 to expand and expand seal 59 outward into contact with the hole surface. The packer can then be pressurized through connector 52.

CLAIMS.

1. A method of fracturing rock comprising the steps of:-
drilling (1) a hole into the rock required to be fractured;
modifying the hole (2,5) drilled to enable cracking to initiate at the point of modification;
pressurizing the hole rapidly (3) with liquid to fracture a fragment of rock from the rock to be fractured; and
removing the cracked fragment from the rock (4).

2. A method according to claim 1 wherein the rapid pressurization step comprises:-
injecting a liquid into the modified hole (19) to initiate cracking; and continuing to inject liquid until a crack (22) reaches the rock surface (23).

3. A method according to claim 2 wherein the injection to the point at which cracking is initiated is accomplished in less than 1/50th of a second.

4. A method according to any preceding claim wherein the modifying step includes cutting a slot from the hole (18) in the direction in which fracturing is required.

5. A method according to any preceding claim wherein the modifying step includes cutting a disc (19) from the hole at the point at which fracturing

is required.

6. A method according to claim 5 wherein the disc (19) is cut at an angle from 30° to 150° to the hole (18).

7. An apparatus for fracturing rock comprising:-
power means (11) to power the apparatus;
drilling means (13) connected to the power means for drilling a hole (18) in the rock (21) required to be fractured;
hole modification means (13) connected to the power means for modifying the hole drilled by the drilling means; and
pressurization means (14) connected to the power means for rapidly pressurizing the hole modified by the hole modification means.

8. An apparatus according to claim 7 wherein the drilling means is a water jet drill.

9. An apparatus according to claim 7 or claim 8 wherein the hole modification means is a tool (13) for cutting a disc at the end of a hole.

10. An apparatus according to any of claims 7 to 9 wherein the pressurization means comprises liquid injection means connected to the power means for injecting liquid into the hole; and containment means connected to the liquid injection means for containing

liquid during the injection of the liquid into the hole.

11. An apparatus according to claim 10 wherein the injection means comprises:-

accumulator means (14) connected to the power means for providing a body of high pressure liquid;

release means (16) connected to the accumulator means (14) for rapidly releasing liquid from the accumulator means; and

packer means (31, 36) connected to the release means and seal means for packing liquid into the hole.

12. An apparatus according to claim 11 wherein the release means is a rapidly operating valve (16).

13. An apparatus according to claim 11 or claim 12 wherein the packer means (31, 36) includes means (38, 47) for securing the packer means to the hole during injection of liquid.

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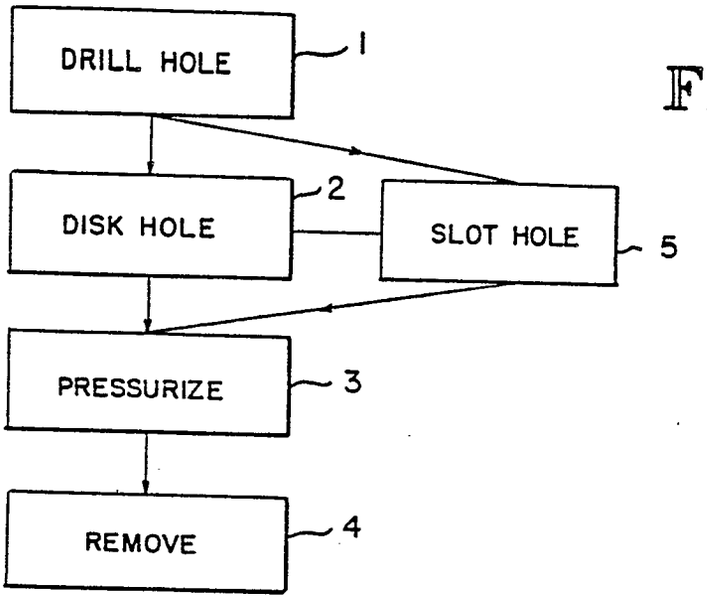
DRILL HOLE
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DISK HOLE
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SLOT HOLE
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PRESSURIZE
3
REMOVE
4

FIG. 1

FIG. 2

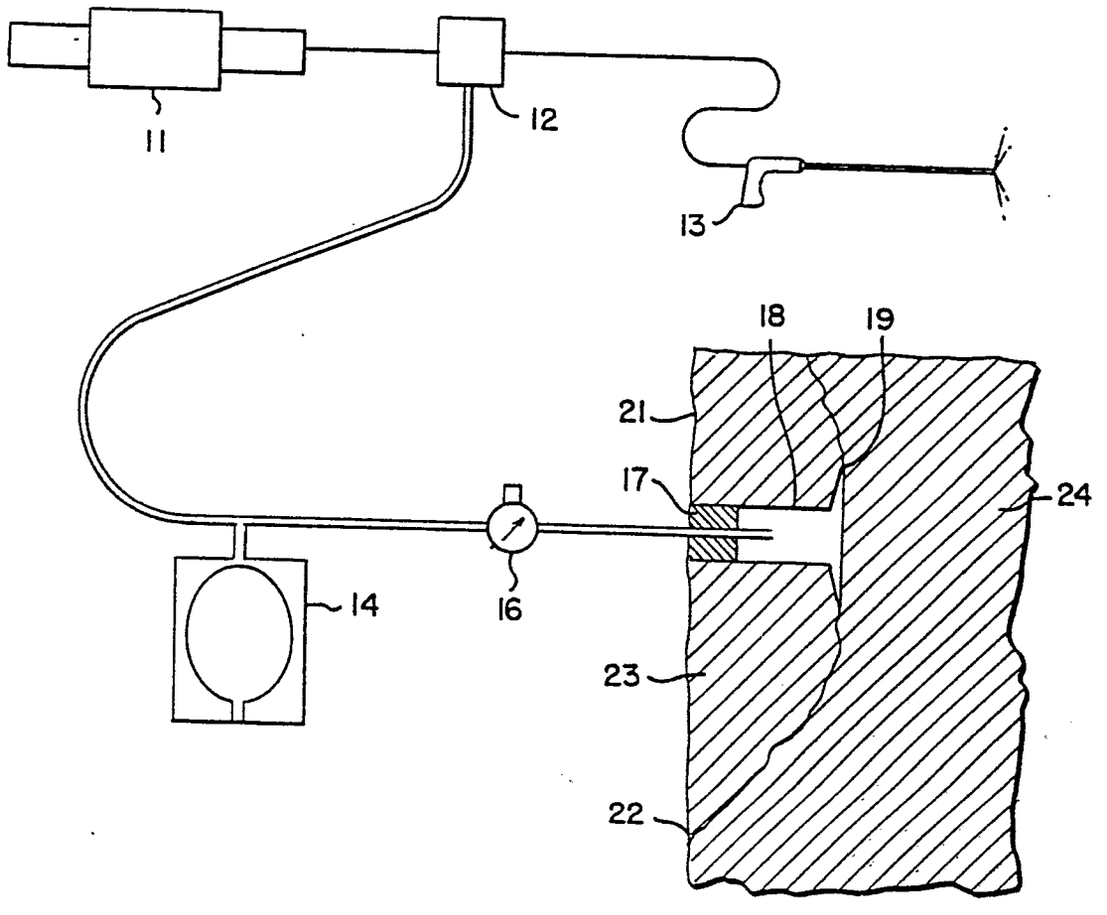
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FIG. 3

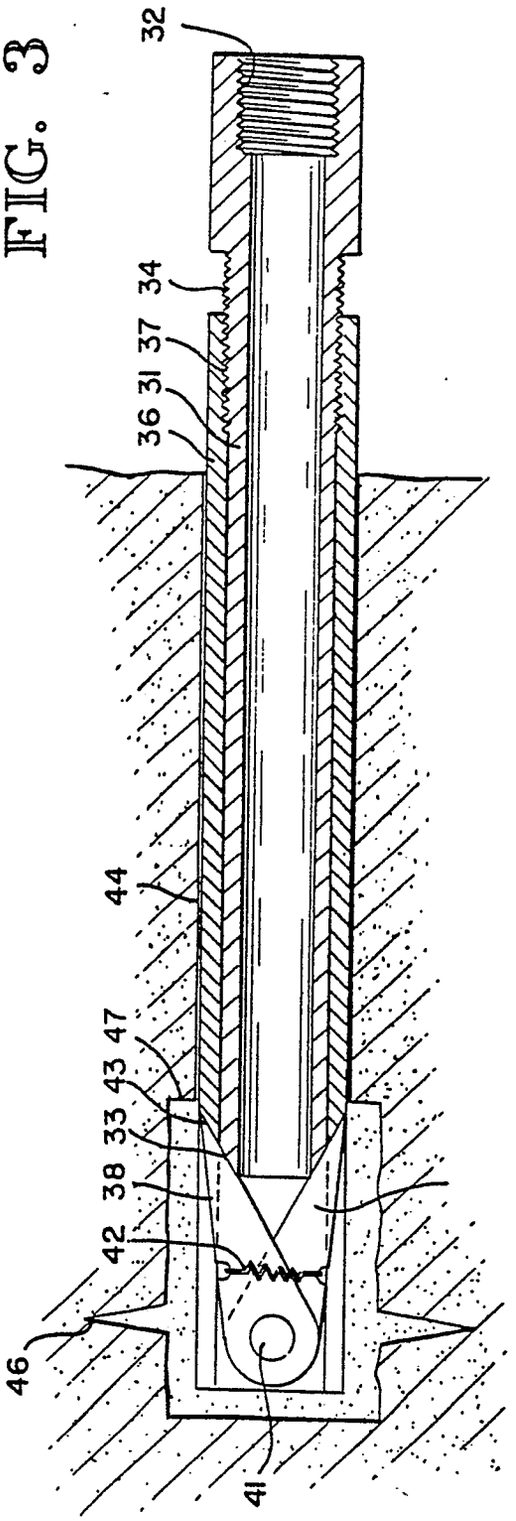

FIG. 4