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(54) **BEDROCK CRACKING APPARATUS USING ICE BOMB IN SHAPE OF POWDER KEG**

**FELSBODENAUFBRECHVORRICHTUNG ANHAND EINER EISBOMBE IN FORM EINES
PULVERFASSES**

**APPAREIL DE FISSURATION DE LIT ROCHEUX À L'AIDE D'UNE BOMBE À GLACE DE LA FORME
D'UN BARIL DE POUDRE**

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KR-Y1- 200 215 836 US-A- 1 920 094
US-A- 2 145 473**

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Description

TECHNICAL FIELD

[0001] The present invention relates to a bedrock crack apparatus using a powder keg type ice explosive, and in particular to a bedrock crack apparatus using a powder keg type ice explosive wherein a via hole is formed at a bedrock using a via hole apparatus, and a sealed tube filled with water and a liquid nitrogen is inserted in the interior of the via hole, thus causing cracks in the bedrock based on the principle where volume expands when water is frozen and easily cracking the bedrock.

BACKGROUND ART

[0002] In general, a variety of methods are used at a construction site of a tunnel for a road or a railroad, among which a solid bedrock is broken by an explosive, and an excavation work is conducted by an excavator.

[0003] In recent years, a tunnel boring machine (TBM), large scale equipment, has been developed and used so as to effectively construct a tunnel without using an explosive. The tunnel construction method of using the TBM is an environment friendly tunnel excavation and construction method which is characterized in that an excavation work is performed creating a circular cross section when viewing the excavated tunnel, so such a method is a kind of a machine-based excavation which is safe and does not cause any vibration because any explosive is not used, thanks to which a ground transformation may be minimally reduced during a ground excavation work, thus maximally securing safety during the construction work. In addition, environment destroy due to noise, vibration, etc. may be minimized, thus securing a safe and clean working environment inside the tunnel.

[0004] The above-mentioned tunnel excavation apparatus is able to excavate at once the whole cross sections of a tunnel by rotating a disk-shaped excavation head attached with bits, cuts, etc. or is able to freely excavate a predetermined cross section by freely moving a drum attached with bits, cuts, etc. The above-mentioned tunnel excavation apparatus may be more effectively used when constructing a tunnel at a relatively solid ground like in a mountain area.

[0005] As an example of the above-described tunnel excavation apparatus, there is the Korean utility model registration number 0368000 as illustrated in Figures 1 and 2, which may include a center shaft 10 wherein a center core drill 12 provided at a front end forms a center groove during rotations by a driving unit 13, and a piston 14 is rotatably engaged through a slide sheet for the sake of forward and backward movements at an intermediate portion of its longitudinal direction, a cylinder member 20 wherein the center shaft 10 is rotatably engaged along an axial direction thereof, and a slide space 22 is formed inside of the same for moving forward and backward the center shaft 10 as the piston 14 is slide-inserted in for-

ward and backward directions and moves forward or backward within a predetermined range for hereby moving forward or backward the center shaft 10, an outer side core groove via hole member 30 wherein the center of a rotation plate 31 is integrally inserted into a front end drill engaging part of the center shaft 10, and a core tube 32 is engaged to a rim portion of the rotation plate 31 while protruding by the length of a center core drill 12, and a cutting bite is engaged to a front rim end of the core tube 32 for the sake of the formation of a core groove, and there is provided at least one worker guide hole 34 formed along the circumference of the rotation plate 31 for a work to pass through the worker guide hole 34, and the outer side core groove via hole member 30 rotates together with the center shaft 10, a support member 40 which is engaged to an outer side of the cylinder member 20 and is positioned at an inner wall of a hole formed by means of the outer side core groove via hole member 30 and is selectively fixed at an inner wall of the hole through a plurality of jacks 41 provided at an outer side end, at least one crushing core drill member 50 which is detachably engaged to the rotation plate 31 of the outer side core groove via hole member 30, wherein a core drill provided at its front end independently rotates by the driving unit 13, and a controller 60 for controlling each component when electric power is supplied.

[0006] The technology described in the Korean utility model registration number 0368000 has advantages in the way that the whole cross sections of the tunnel are excavated at once by rotating a disk-shaped excavation head attached with bits, cuts, etc., or a predetermined cross section may be freely excavated by freely moving the drum attached with bits, cuts, etc.; however when excavating a tunnel, a plurality of holes are formed at the surfaces of the bedrock using a center core drill and a plurality of core drills, and then cracking work is performed. In this case, excavation efficiency of a bedrock is low, and since an outer side core groove via hole member and various cutters may be worn out, so it is hard to efficiently prevent the shortening of service life.

[0007] The Patent Document KR100614795 discloses an air bedrock breaking apparatus having the features of the preamble of the main claim.

DISCLOSURE OF THE INVENTION

[0008] Accordingly, the present invention is made to resolve the above-mentioned problems.

[0009] It is an object of the present invention to provide a bedrock crack apparatus using a powder keg type ice explosive wherein a via hole is formed at a bedrock using a via hole apparatus, and a sealed tube filled with water and a liquid nitrogen is inserted in the interior of the via hole, thus causing cracks in the bedrock based on the principle where volume expands when water is frozen and easily cracking the bedrock.

[0010] It is another object of the present invention to provide a bedrock crack apparatus using a powder keg

type ice explosive wherein when injecting nitrogen into a via hole formed at a bedrock using a via hole apparatus, a flange is formed at an end portion of an injection device, thus reliably sealing the mouth of a via hole, and a liquid nitrogen is injected through a nitrogen injection nozzle provided at an injection device, thus more easily causing cracks with the aid of freezing and expansion of the water tube itself.

[0011] It is further another object of the present invention to provide a bedrock crack apparatus using a powder keg type ice explosive wherein nitrogen is injected into a via hole formed at a bedrock using a via hole apparatus, and the mouth of the via hole is sealed with a packer, and a nozzle of the injection device is inserted in a via hole of the packer, thus injecting liquid nitrogen into the interior of the via hole, so it is possible to reliably cause cracks at a bedrock with the aid of freezing and expansion of the water tube.

[0012] It is still further another object of the present invention to provide a bedrock crack apparatus using a powder keg type ice explosive wherein when water and nitrogen are injected into a via hole formed at a bedrock, the mouth of the via hole is sealed with a packer. At this time, a tube filled with water is provided inside of the packer, thus eliminating a process for injecting water, so it is possible to fast cause cracks at a bedrock.

[0013] It is still further another object of the present invention to provide a bedrock crack apparatus using a powder keg type ice explosive wherein when a via hole is formed using a via hole apparatus at a bedrock, cracks may have been formed inside of the via hole, so water may leak out when injecting water. In order to prevent the above phenomenon, a gel may be injected inside of the bedrock, and then water and liquid nitrogen may be injected, thus preventing leakage of water, by which cracks may be reliably caused at the bedrock.

[0014] To achieve the above objects, there is provided a bedrock crack apparatus using a powder keg type ice explosive, which may include a packer which is fixedly inserted in the mouth of a via hole formed at a bedrock; an inner tube which is disposed at the packer and is filled with water; an injection device which is connected to the packer; a nitrogen injection nozzle which is installed at the injection device and passes through the packer; and a supply unit which is connected to the injection device and is configured to supply liquid nitrogen.

[0015] In addition, the packer includes a nitrogen discharge tube.

[0016] Here, an outer tube is provided at an outer side of the inner tube.

[0017] At this time, the nitrogen injection nozzle is configured to inject nitrogen into between the inner tube and the outer tube.

[0018] In addition, a plurality of first pressurization protrusions are formed on an outer circumferential surface of the inner tube.

[0019] Meanwhile, a plurality of second pressurization protrusions are formed on an inner circumferential sur-

face of the outer tube.

[0020] Here, a gel or sand is injected in the via hole, and then the packer is fixedly inserted.

[0021] In addition, the packer is inserted into the via hole, and then a gel or sand is injected.

[0022] At this time, the packer is configured to seal the mouth of the via hole.

[0023] In addition, the packer is inserted into the interior of the via hole.

INDUSTRIAL EFFECTS

[0024] The present invention may provide the following advantageous effects. A via hole is formed at a bedrock using a via hole apparatus, and a sealed tube filled with water and a liquid nitrogen is inserted in the interior of the via hole, thus causing cracks in the bedrock based on the principle where volume expands when water is frozen and easily cracking the bedrock.

[0025] In addition, according to the present invention, when injecting nitrogen into a via hole formed at a bedrock using a via hole apparatus, a flange is formed at an end portion of an injection device, thus reliably sealing the mouth of a via hole, and a liquid nitrogen is injected through a nitrogen injection nozzle provided at an injection device, thus more easily causing cracks with the aid of freezing and expansion of the water tube itself.

[0026] In addition, according to the present invention, nitrogen is injected into a via hole formed at a bedrock using a via hole apparatus, and the mouth of the via hole is sealed with a packer, and a nozzle of the injection device is inserted in a via hole of the packer, thus injecting liquid nitrogen into the interior of the via hole, so it is possible to reliably cause cracks at a bedrock with the aid of freezing and expansion of the water tube.

[0027] In addition, according to the present invention, when water and nitrogen are injected into a via hole formed at a bedrock, the mouth of the via hole is sealed with a packer. At this time, a tube filled with water is provided inside of the packer, thus eliminating a process for injecting water, so it is possible to fast cause cracks at a bedrock.

[0028] In addition, according to the present invention, when a via hole is formed using a via hole apparatus at a bedrock, cracks may have been formed inside of the via hole, so water may leak out when injecting water. In order to prevent the above phenomenon, a gel may be injected inside of the bedrock, and then water and liquid nitrogen may be injected, thus preventing leakage of water, by which cracks may be reliably caused at the bedrock.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The present invention will become better understood with reference to the accompanying drawings which are given only by way of illustration and thus are not limitative of the present invention, wherein;

Figure 1 is a cross sectional view illustrating a conventional tunnel excavator;

Figure 2 is a cross sectional view taken along line B'-B' of Figure 1;

Figure 3 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to the present invention;

Figure 4 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to another exemplary embodiment of the present invention;

Figure 5 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to further another exemplary embodiment of the present invention;

Figure 6 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to still further another exemplary embodiment of the present invention;

Figure 7 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to still further another exemplary embodiment of the present invention;

Figure 8 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to still further another exemplary embodiment of the present invention;

Figure 9 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to still further another exemplary embodiment of the present invention; and

Figure 10 is a concept view illustrating a dual vacuum tube used at a bedrock crack apparatus using a powder keg type ice explosive according to the present invention.

MODES FOR CARRYING OUT THE INVENTION

[0030] The exemplary embodiments of the present invention will be described with reference to the accompanying drawings. The same components in the drawings will be given the same reference numbers. The descriptions on the same components may be omitted. It should be understood that the present invention may be implemented in various forms and is not limited to the disclosed embodiments.

[0031] Figure 3 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to the present invention, Figure 4 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to another exemplary embodiment of the present invention, Figure 5 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to further another exemplary embodiment of the present invention, Figure 6 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to still further another exemplary embodiment of the

present invention, Figure 7 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to still further another exemplary embodiment of the present invention, Figure 8 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to still further another exemplary embodiment of the present invention, Figure 9 is a concept view illustrating a bedrock crack apparatus using a powder keg type ice explosive according to still further another exemplary embodiment of the present invention, and Figure 10 is a concept view illustrating a dual vacuum tube used at a bedrock crack apparatus using a powder keg type ice explosive according to the present invention.

[0032] The present invention is directed to a bedrock crack apparatus using a powder keg type ice explosive. As illustrated in Figure 3, the bedrock crack apparatus using a powder keg type ice explosive wherein a via hole 310 may be formed at a bedrock 300 using a variety of via hole apparatuses (not shown), for example, a laser drill, a drill, a jumbo drill, a water jet, etc., may include a packer 200 which is fixedly inserted in the mouth of the via hole 310, an injection device 100' connected to the packer 200, an inner tube 230 which is provided at the packer 200 and is filled with water, a nitrogen injection nozzle 130 which is installed at the injection device 100' and passes through the packer 200, and a supply unit (not shown) which is connected to the injection device 100' and supplies liquid nitrogen. Since the configuration of the supply unit for supplying liquid nitrogen is known in the art, descriptions thereof may be omitted.

[0033] The injection device 100' is configured to inject liquid nitrogen through a nitrogen injection nozzle 130 into an outer side of the inner tube 230, thus fast cooling the water in the inner tube 230 and converting the water into ice.

[0034] At this time, when water is frozen, the volume of the water expands. Cracks may be caused at the outer wall of the via hole 310 by expansion force generating when the volume of the water expands since the water in the inner tube 230 changes into ice, thus easily breaking the bedrock 300.

[0035] In addition, a nitrogen discharge tube 250 is provided at one side of the packer 200 so as to discharge nitrogen which has been injected through the nitrogen injection nozzle 130. The nitrogen discharge tube 250 is connected to the injection device 100', so the nitrogen can be discharged outside through the injection device 100'.

[0036] Meanwhile, as illustrated in Figure 10, the nitrogen injection nozzle 130 and the nitrogen discharge tube 250 are made of a vacuum dual tube. The vacuum dual tube consists of an inner tube 132 and an outer tube 134, and a vacuum space is formed between the inner tube 132 and the outer tube 134.

[0037] When liquid nitrogen is injected into the interior of the via hole 310 through the nitrogen injection nozzle 130, any heat loss may be prevented since external at-

mosphere does not affect.

[0038] In addition, the technology of the present invention may use a conventional TBM (rotation cut excavation) technology or NATM technology (via hole and explosive explosion).

[0039] Meanwhile, the injection device 100' may be connected to the nitrogen discharge tube 250. Alternatively, as illustrated in Figure 4, the injection device 100' may be installed at the packer 200, not connected to the nitrogen discharge tube 250, thus directly discharging the nitrogen to the outside through the nitrogen discharge tube 250.

[0040] In addition, as illustrated in Figure 5, an outer tube 240 may be further provided at an outer side of the inner tube 230. The injection nozzle 130 passing through the packer 200 serves to inject nitrogen into between the inner tube 230 and the outer tube 240.

[0041] In addition, the nitrogen discharge tube 250 may be positioned between the outer tube 240 and the inner tube 230, thus discharging the injected nitrogen to the outside.

[0042] At this time, the inner tube 230 maybe made of a metallic material, and the outer tube 240 may be made of a rubber material.

[0043] In addition, the nitrogen injection nozzle 130 and the nitrogen discharge tube 250 are made of a vacuum dual tube.

[0044] Meanwhile, as illustrated in Figure 6, first pressurization protrusions 232 are formed at regular intervals on an outer circumferential surface of the inner tube 230. Here, the nitrogen injection nozzle 130 and the nitrogen discharge tube 250 may be disposed between the first pressurization protrusions 232.

[0045] When the water filled in the inner tube 230 is fast frozen with the aid of the liquid nitrogen, the first pressurization protrusions 232 pressurize the outer tube 240, thus pressurizing the inner circumferential surface of the via hole 310. Therefore, the via hole 310 may be pressurized by higher pressure with the aid of the first pressurization protrusions 232, thus easily causing cracks.

[0046] As illustrated in Figure 7, second pressurization protrusions 242 may be formed on an inner circumferential surface of the outer tube 240. The pressure of the expansion force generating when water in the inner tube 230 is frozen into ice with the aid of the liquid nitrogen more increases, thus more easily causing cracks at the via hole 310.

[0047] In addition, since the first and second pressurization protrusions 232 and 242 are formed in the inner tube 230 and the outer tube 240, the convention heat transfer efficiency of the injected liquid nitrogen may increase, so the expansion force may be uniformly distributed, and the bedrock are broken into small pieces with the aid of expansion.

[0048] Meanwhile, according to another exemplary embodiment of the present invention as illustrated in Figure 8, a gel 320 or sand 330 may be previously injected

in the via hole 310, and the packer 200 may be fixedly inserted. The gel 320 and the sand 330 may block fine cracks formed on the inner circumferential surface of the via hole 310, so it is possible to prevent the liquid nitrogen injected into the via hole from leaking to the outside. In case where the tube 220, the inner tube 230 and the outer tube 240 are installed at the packer 200, the gel and sand may fill in the spaces between the via hole 310 and the tube 220, the inner tube 230 and the outer tube 240, so the pressure may increase more than the pressure when the volume expands when water changes into ice, thus more easily causing cracks.

[0049] Here, the diameter of the packer 200 may be same as the inner diameter of the mouth of the via hole 310 or may be larger a bit, so the packer 200 may shrink-fit the mouth, thus reliably sealing the mouth, whereby it is possible to generate higher expansion pressure when water changes into ice.

[0050] At this time, the sand 330 may be wet sand or dry sand.

[0051] In addition, as illustrated in Figure 9, the packer 200 with the tube 220 or the inner and outer tubes 230 and 240 are injected in the via hole 310, and then the gel 320 or the sand is filled, and the spaces between the tube 220, the inner tube 230 and the outer tube 240 are filled. When the water changes into ice, the expansion pressure may be increase higher, thus easily causing cracks.

[0052] At this time, the outer diameters of the tube 220, the inner and outer tubes 230 and 240 and the packer 200 are made smaller than the inner diameter of the via hole 310, so wet sand or dry sand can be easily injected, and the tube 220, the inner and outer tubes 230 and 240 and the packer 200 may be fully inserted into the interior of the via hole 310.

[0053] The rests of the components are same as the previously described components, so the descriptions thereon will be omitted.

INDUSTRIAL APPLICABILITY

[0054] The present invention is directed to a bedrock crack apparatus using a powder keg type ice explosive, and in particular to a bedrock crack apparatus using a powder keg type ice explosive wherein a via hole is formed at a bedrock using a via hole apparatus, and a sealed tube filled with water and a liquid nitrogen is inserted in the interior of the via hole, thus causing cracks in the bedrock based on the principle where volume expands when water is frozen and easily cracking the bedrock.

Claims

1. A bedrock crack apparatus using a powder keg type ice explosive, comprising:

a packer (200) which is fixedly inserted in the mouth of a via hole (310) formed at a bedrock (300);

an inner tube (230) which is disposed at the packer (200) and is filled with water;

an injection device (100') which is connected to the packer (200);

characterized by a nitrogen injection nozzle (130) which is installed at the injection device (100') and passes through the packer (200); and a supply unit which is connected to the injection device (100') and is configured to supply liquid nitrogen,

and further **characterized in that** an outer tube (240) is provided at an outer side of the inner tube (230), and **in that** the nitrogen injection nozzle (130) is configured to inject liquid nitrogen into between the inner tube (230) and the outer tube (240).

2. The apparatus of claim 1, wherein the packer (200) includes a nitrogen discharge tube (250).
3. The apparatus of claim 1, wherein a plurality of first pressurization protrusions (232) are formed on an outer circumferential surface of the inner tube (230).
4. The apparatus of claim 1, wherein a plurality of second pressurization protrusions (242) are formed on an inner circumferential surface of the outer tube (240).
5. The apparatus of claim 1, wherein a gel (320) or sand (330) is injected in the via hole (310), and then the packer (200) is fixedly inserted.
6. The apparatus of claim 1, wherein the packer (200) is inserted into the via hole (310), and then a gel (320) or sand (330) is injected.
7. The apparatus of either claim 5 or claim 6, wherein the packer (200) is configured to seal the mouth of the via hole (310).
8. The apparatus of either claim 5 or claim 6, wherein the packer (200) is inserted into the interior of the via hole (310).

Patentansprüche

1. Ein Festgesteinaufbruchsapparat unter Verwendung eines pulverfaßartigen Eis-Sprengstoffs, umfassend

ein Packteil (200), das fixiert in den Mund eines Durchlochs (310), das bei einem Felsgestein (300) gebildet ist, eingeführt ist,

ein Innenrohr (230), welches an dem Packteil (200) angeordnet ist und mit Wasser gefüllt ist; eine Injektionsvorrichtung (100'), welche mit dem Packteil (200) verbunden ist;

gekennzeichnet durch eine Stickstoffinjektionsdüse (130), welche an der Injektionsvorrichtung (100') installiert ist und durch das Packteil (200) hindurchführt; und

eine Versorgungseinheit, welche mit der Injektionsvorrichtung (100') verbunden ist und ausgelegt ist, flüssigen Stickstoff bereitzustellen, und

weiter **gekennzeichnet durch** ein Außenrohr (240), das an der Außenseite des Innenrohrs (230) vorgesehen ist,

und **dadurch, dass** die Stickstoffinjektionsdüse (130) ausgelegt ist, flüssigen Stickstoff zwischen das Innenrohr (230) und das Außenrohr (240) zu injizieren.

2. Der Apparat nach Anspruch 1, wobei das Packteil (200) eine Stickstoffabgaberöhre (250) einschließt.
3. Der Apparat nach Anspruch 1, wobei eine Mehrzahl der ersten Druckerzeugungsauskragungen (232) auf einer Außenumfangsoberfläche des Innenrohrs (230) gebildet ist.
4. Der Apparat nach Anspruch 1, wobei die Mehrzahl der zweiten Druckerzeugungsauskragungen (242) auf einer Innenumfangsoberfläche des Außenrohrs (240) gebildet ist.
5. Der Apparat nach Anspruch 1, wobei ein Gel (320) oder Sand (330) in das Durchloch ("via hole") (310) injiziert wird, und dann das Packteil (200) fixiert eingeführt ist.
6. Der Apparat nach Anspruch 1, wobei das Packteil (200) in das Durchloch ("via hole") (310) eingeführt ist und dann ein Gel (320) oder Sand (330) injiziert wird.
7. Der Apparat nach entweder Anspruch 5 oder 6, wobei das Packteil (200) ausgelegt ist, um dem Mund des Durchlochs (310) dichtfest zu verschließen.
8. Der Apparat nach entweder Anspruch 5 oder 6, wobei das Packteil (200) in das Innere des Durchlochs (310) eingeführt ist.

Revendications

1. Appareil de fissuration de roche mère au moyen d'une bombe de glace de type a baril de poudre, comprenant :

- une garniture (200) insérée de manière fixe dans la bouche d'un trou traversant (310) formé au niveau d'une roche mère (300) ;
 un tube intérieur (230) situé au niveau de la garniture (200) et remplie d'eau ; 5
 un dispositif d'injection (100') relié à la garniture (200) ; **caractérisé par** une buse d'injection d'azote (130) installée au niveau du dispositif d'injection (100') et passant par la garniture (200) ; et une unité d'alimentation reliée au dispositif d'injection (100') et conçue pour alimenter de l'azote liquide, 10
 et caractérisé également en ce qu'un tube extérieur (240) est situé sur le côté extérieur du tube intérieur (230), 15
 et en ce que la buse d'injection d'azote (130) est conçue pour injecter de l'azote liquide entre le tube intérieur (230) et le tube extérieur (240) .
2. Appareil selon la revendication 1, dans lequel la garniture (200) comprend un tube de décharge d'azote (250). 20
3. Appareil selon la revendication 1, dans lequel une pluralité de premières saillies de pressurisation (232) sont formées sur une surface circonférentielle extérieure du tube intérieur (230) . 25
4. Appareil selon la revendication 1, dans lequel une pluralité de secondes saillies de pressurisation (242) sont formées sur une surface circonférentielle intérieure du tube extérieur (240) . 30
5. Appareil selon la revendication 1, dans lequel un gel (320) ou du sable (330) est injecté dans le trou traversant (310) et la garniture (200) est insérée de façon fixe par la suite. 35
6. Appareil selon la revendication 1, dans lequel la garniture (200) est insérée dans le trou traversant (310), et un gel (320) ou du sable (330) est injecté par la suite. 40
7. Appareil selon la revendication 5 ou la revendication 6, dans lequel la garniture (200) est conçue pour sceller la bouche du trou traversant (310). 45
8. Appareil selon la revendication 5 ou la revendication 6, dans lequel la garniture (200) est insérée à l'intérieur du trou traversant (310). 50

55

Figure 1

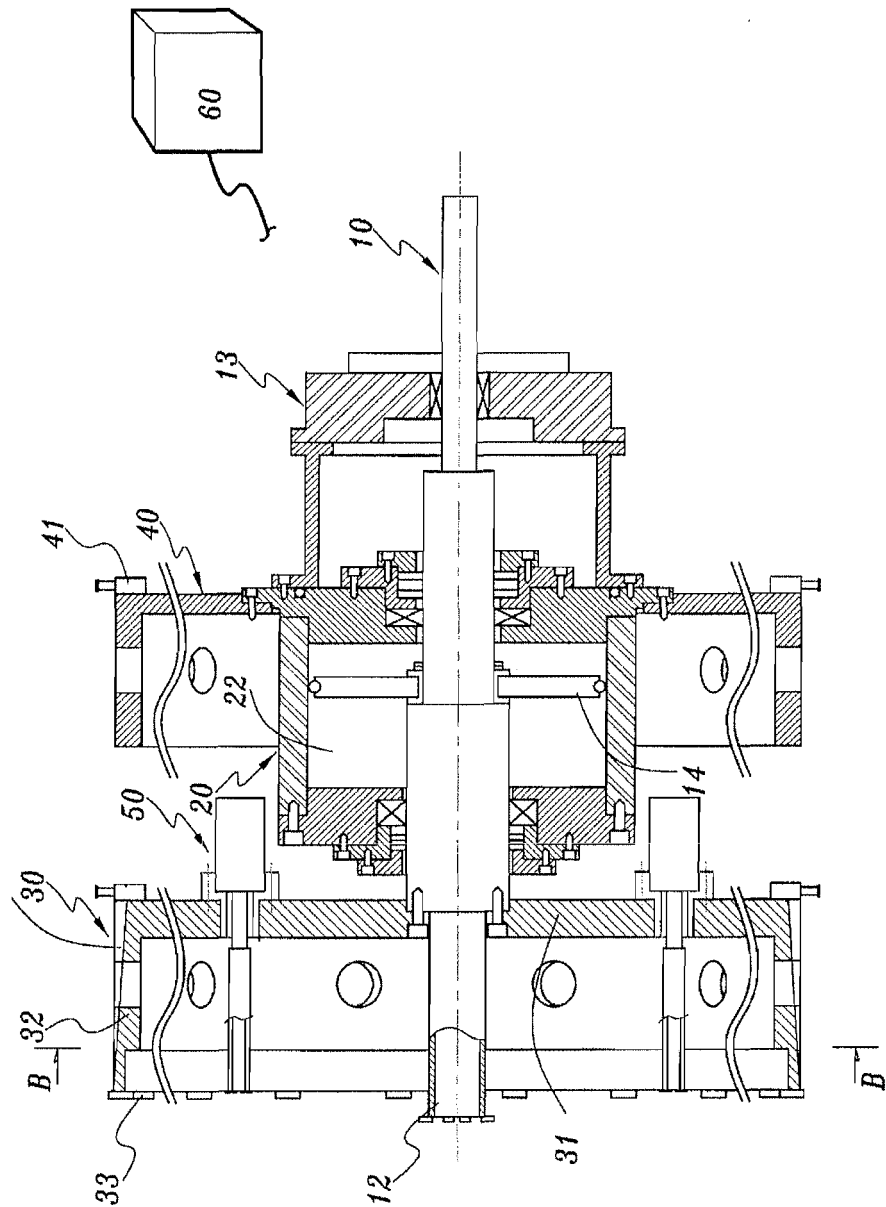


Figure 2

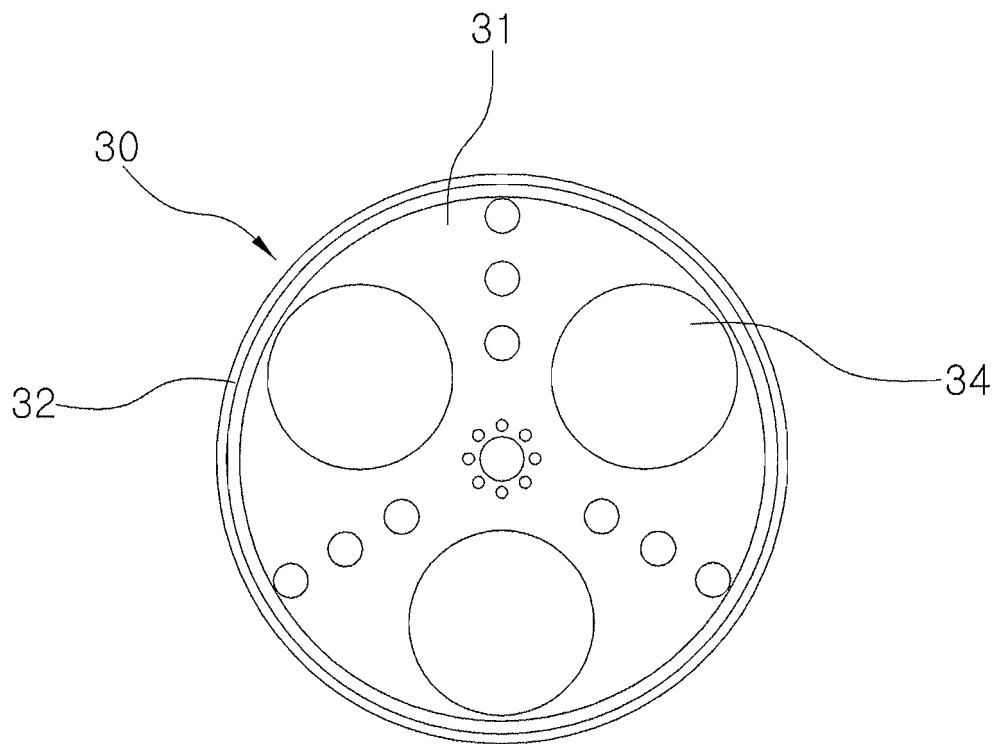
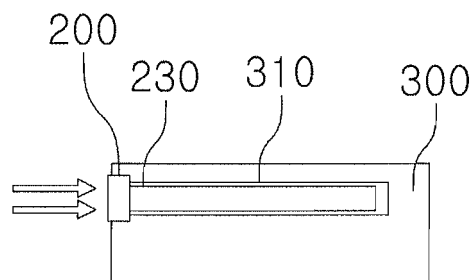


Figure 3

(a)



(b)

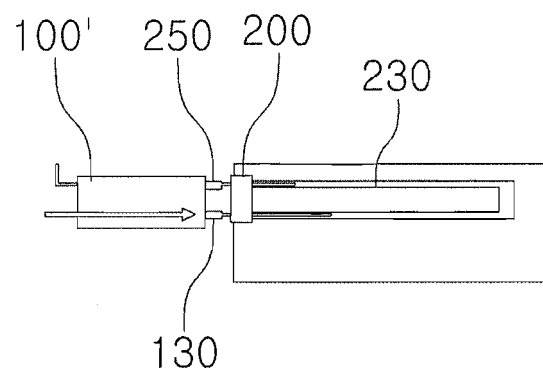


Figure 4

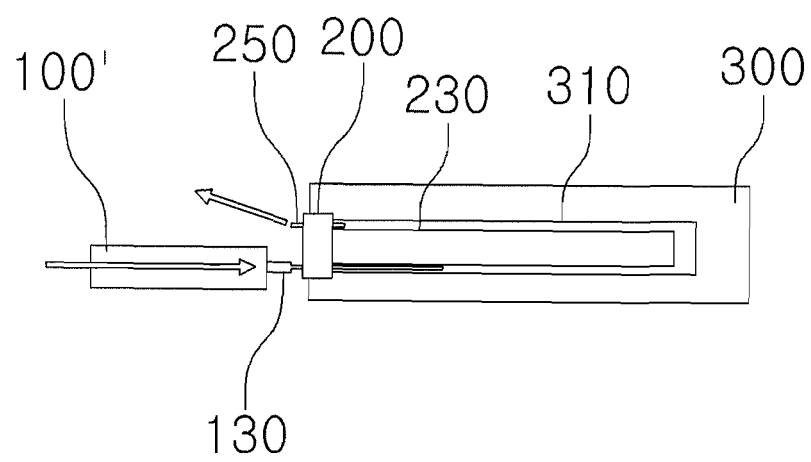


Figure 5

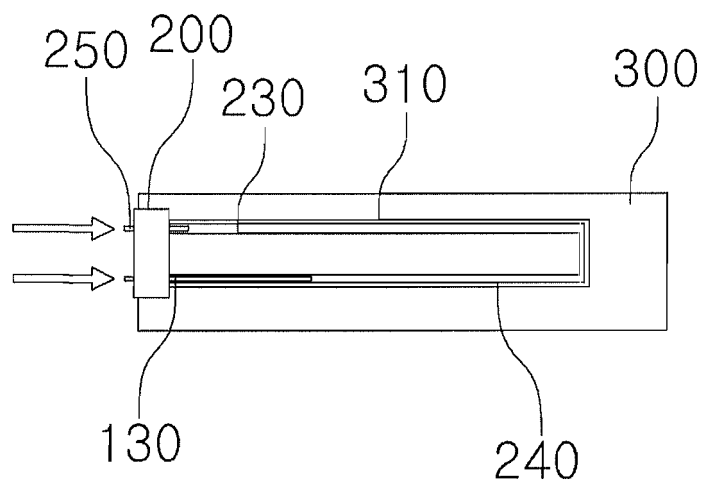


Figure 6

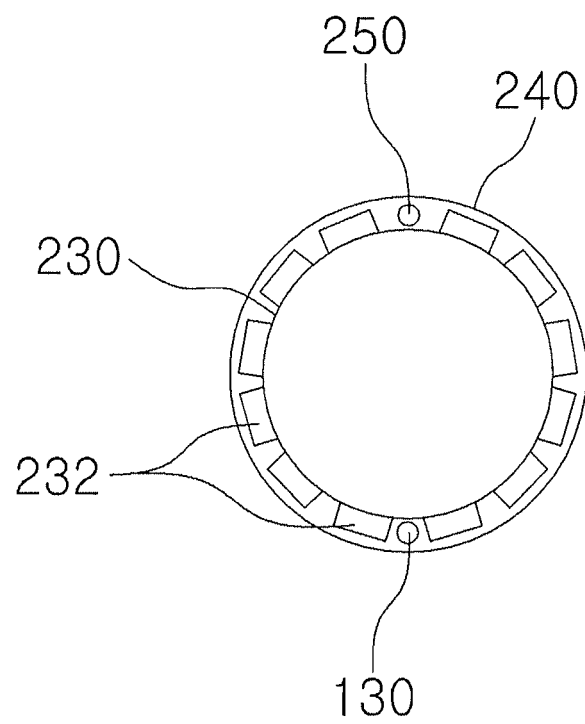


Figure 7

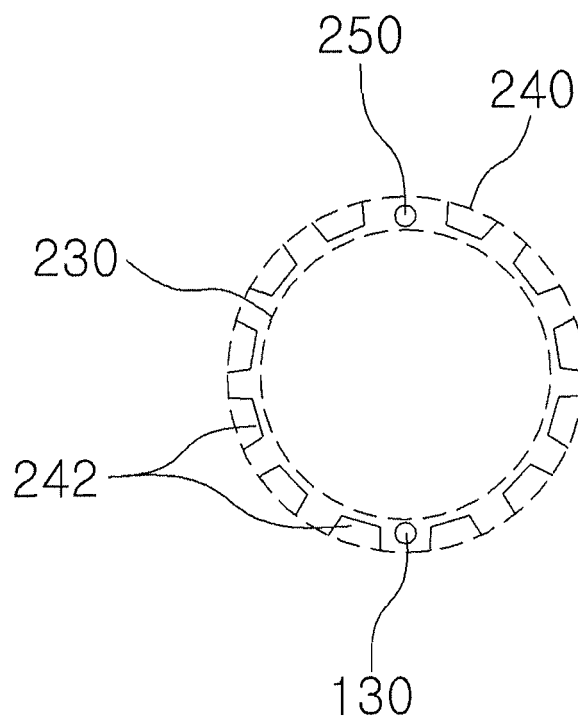


Figure 8

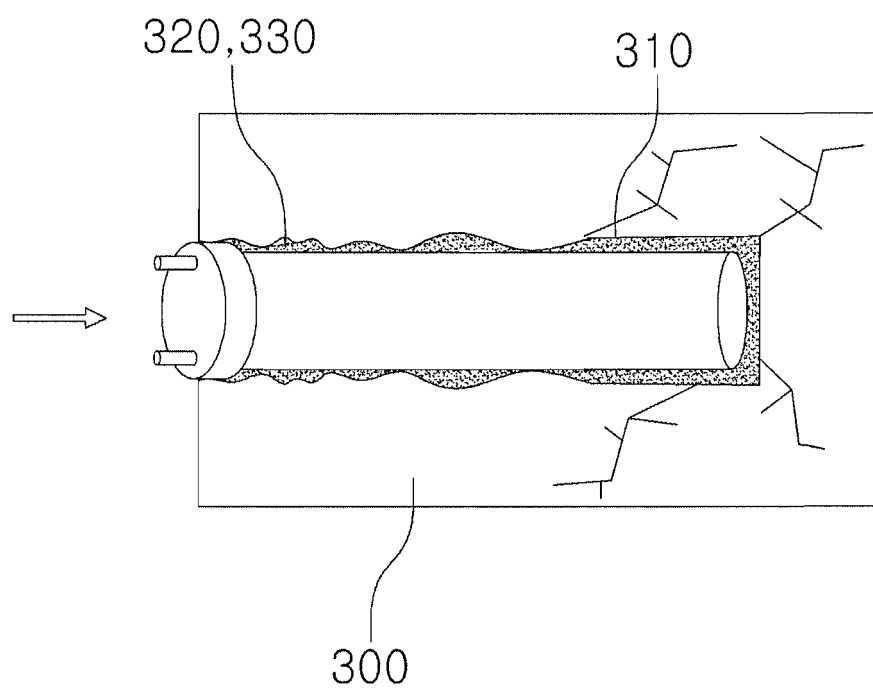


Figure 9

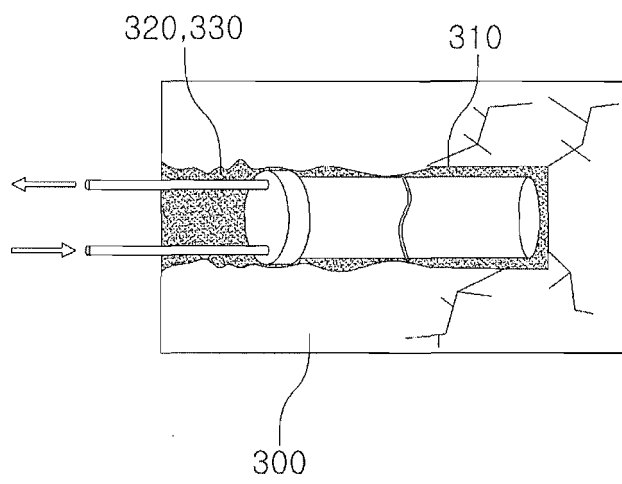
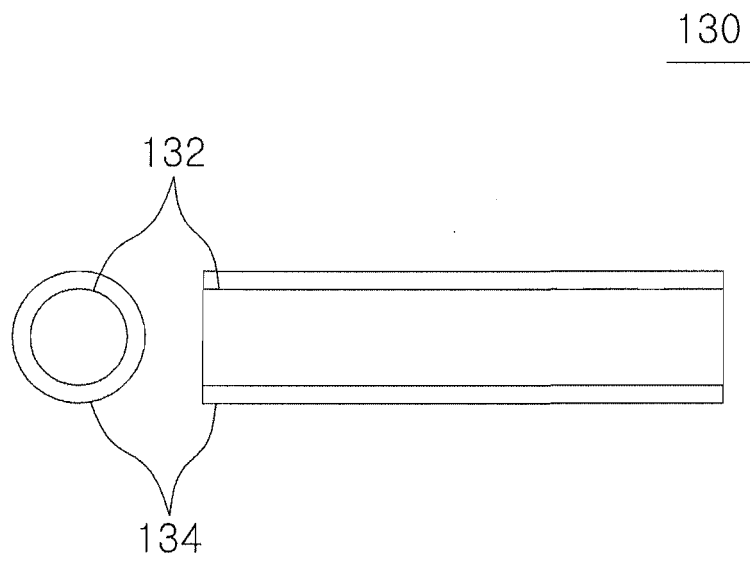


Figure 10



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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