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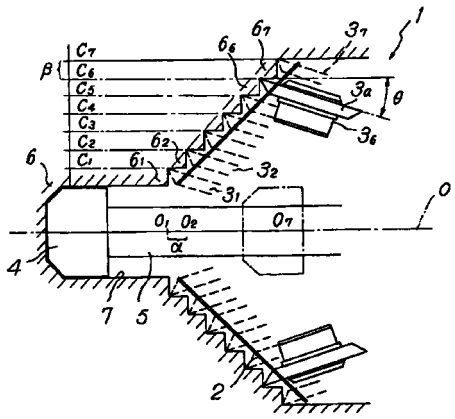
(54) Tunnel excavating process and tunnel excavator

(57) Provided are a tunnel excavating process which can reduce pressure required in excavation and excavate under lower pressure than the prior art even if compressive strength of base rocks is high, and a tunnel excavator capable of suitably executing the process. A plurality of roller cutter groups are arranged at given intervals in an excavating direction and in a direction vertical thereto, and points of roller cutters belonging to each roller cutter group in contact with base rocks are located in the vicinity of a difference in level portion formed in the base rocks to excavate the base rocks. There is constituted a tunnel excavator 1 in which a plurality of roller cutter groups 3x are arranged at given intervals in an excavating direction and in a direction vertical thereto on a cutter head 2 having a substantially conical shape. A boring head 4 can be disposed coaxial with the cutter head 2 to bore a pilot tunnel 7.

FIG. 2



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a tunnel excavating process and a tunnel excavator applying the same which is suitable for excavating the entire section of base rocks to excavate a mine cavity, a tunnel, a vertical shaft and so on

Description of the Prior Art

[0002] As a tunnel excavator which is suitable for excavating the entire section of base rocks to excavate a mine cavity, a tunnel, a vertical shaft and so on, an entire section type tunnel excavator has been heretofore known. The entire section type tunnel excavator is provided with a cutter head having a number of roller cutters mounted thereon whereby the cutter head is moved forward while pressing the cutter head against the base rocks and rotating the cutter head to excavate a circular section to excavate the tunnel or the like.

[0003] In the conventional entire section type tunnel excavator, in a front portion of the cutter head, the roller cutters are arranged so as to come in contact, simultaneously and at right angles on substantially one plane and, with the working face of the tunnel vertical to the excavating direction, and in a peripheral portion of the cutter head, the roller cutters are arranged so as to contact, substantially at right angles, with the working face of the tunnel inclined rearward with respect to the excavating direction.

[0004] In the front portion as well as the peripheral portion of the cutter head, base rocks are present substantially equally in the circumference of the point of the roller cutters in contact with the base rocks, and a difference in level portion such as to cut off the base rocks in one direction is not present. Therefore, the roller cutters act against the compressive strength of the base rocks to rupture the base rocks around the point in contact with the rocks by the compressive force.

[0005] Accordingly, in the case where the compressive force of the base rocks is high, extremely high pressure is necessary to rupture the base rocks, resulting in a material lowering of excavating ability and a severe wear of the roller cutters.

[0006] Further, since the cutter head is pressed against the base rocks under extremely high pressure, it has been necessary to make a more rigid construction roller cutters, a cutter head, and a frame in an attempt of preventing vibrations and flexure, and to make a cutter head pressing cylinder stronger.

SUMMARY OF THE INVENTION

[0007] It is an object of the present invention to provide a tunnel excavating process, which can reduce pressure required in excavation, excavate base rocks under low pressure as compared to the prior art even if the compressive strength of the base rocks is high to prevent a remarkable material lowering of the excavating ability and a severe wear of the roller cutters, and need not to make roller cutters, a cutter head and a frame so rigid and make a cutter head pressing cylinder powerful.

[0008] It is a further object of the invention to provide a tunnel excavator which can suitably carry out the tunnel excavating process.

[0009] For achieving the aforementioned objects, in the tunnel excavating process according to the present invention, a plurality of roller cutter groups are arranged at given intervals in an excavating direction and in a direction vertical thereto, and points of the roller cutters in contact with base rocks belonging to the each roller cutter group are located in the vicinity of a difference in level portion formed in the base rocks to excavate the base rocks.

[0010] The tunnel excavator according to the present invention can suitably execute the aforementioned tunnel excavating process, in which a plurality of roller cutter groups are arranged at given intervals in an excavating direction and in a direction vertical thereto on a cutter head having a substantially conical shape.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 is a schematic front view of a cutter head according to an embodiment of a tunnel excavator in accordance with the present invention; FIG. 2 is a schematic sectional view showing the state in which the tunnel is excavated by means of the tunnel excavator shown in FIG. 1; FIG. 3 is an explanatory view showing the processes for excavating the tunnel by the tunnel excavator shown in FIG. 1; FIG. 4 is an explanatory view showing the state in which the base rocks are excavated by means of a roller cutter; FIG. 5 is a schematic sectional view showing the state in which the tunnel is excavated by means of a further embodiment of the tunnel excavator; and FIG. 6 is a schematic sectional view showing the state in which by means of another embodiment of the tunnel excavator.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] The tunnel excavating process and the tunnel excavator in accordance with the present invention will be explained hereinafter with reference to the accompanying drawings.

[0013] FIG. 1 is a schematic front view of a cutter head of a tunnel excavator in accordance with the present

invention, and FIG. 2 is a schematic sectional view showing the state in which the tunnel is excavated by means of the tunnel excavator shown in FIG. 1. In these figures, only a cutter head 2 disposed in front of the tunnel excavator 1 is shown, and the internal and rear mechanisms of the tunnel excavator such as a retaining mechanism for a roller cutter, a driving mechanism for the cutter head 2, a pressing mechanism and so on are omitted.

[0014] The tunnel excavator 1 is provided with the cutter head 2 having a substantially conical shape, as shown in FIGS. 1 and 2. The cutter head 2 is capable of pressing the working face of the base rocks with desired pressure by means of the pressing mechanism not shown, and can be rotated about a center axis 0 in both normal and reverse directions, and with the desired rotational frequency and rotational torque by means of the driving mechanism not shown.

[0015] As shown in FIGS. 1 and 2, a plurality of groups of roller cutter groups 3_1, 3_2, 3_3 ... are arranged on the cutter head 2 at given intervals in an excavating direction and in a direction vertical thereto.

[0016] More specifically, the roller cutter groups 3_1, 3_2, 3_3 ... are arranged on concentric circles C_1, C_2, C_3 ... whose radiuses are different with points different in position on the center axis 0 being centers 0_1, 0_2, 0_3 ...

[0017] A spacing between the centers 0_1, 0_2, 0_3 ... is set to a given value α, and a difference in radius between the concentric circles C_1, C_2, C_3 ... is set to a given value β.

[0018] Each roller cutter group 3_x, comprises one or more roller cutters 3_{x1}, 3_{x2}, ..., and in each roller cutter group 3_x, the roller cutters 3_{x1}, 3_{x2}, ... are arranged at equal intervals.

[0019] While in FIG. 1, in the roller cutter group 3_1, a single roller cutter 3_{11} is arranged, and in the roller cutter group 3_3, two roller cutters 3_{31}, 3_{32} are arranged symmetrically, it is to be noted that the number of and arranging state of the roller cutters are not particularly limited thereto.

[0020] The roller cutter 3 is detachably and rotatably mounted on a housing secured to the cutter head 2.

[0021] Further, the roller cutter 3 is inclined by a given angle θ in an excavating direction, that is, in a direction of the center axis 0, and the extreme end of a cutter disk 3a is projected forward from the peripheral surface of the cutter head 2.

[0022] If the roller cutter 3 is inclined by a given angle θ in an excavating direction, the side resistance of the cutter disk 3a can be reduced, and the construction in which the cutter head 2 or the like is not placed in contact with the base rocks can be constituted relatively easily.

[0023] A boring head 4 coaxial with the cutter head 2 is disposed on the tunnel excavator 1, and the boring head 4 rotates independently of the cutter head 2 and moves forward and backward along the center axis 0 of the cutter head 2.

[0024] On the boring head 4 can be suitably selectively mounted a roller cutter, a tricorne bit, a conical bit, a down the hole hammer (D.T.H), a boring bit, etc according to the characteristics of base rocks such as compressive strength and to the desired boring speed..

[0025] Further, there is provided a pressing cylinder 5 separately from the pressing mechanism of the cutter head 2. The boring head 4 is moved forward and backward by the pressing cylinder 5 and can be pressed against the base rocks with desired pressure. It can be rotated with the desired rotational frequency and rotational torque independently of the cutter head 2 through the pressing cylinder 5.

[0026] The boring head 4 is moved forward and backward to assume a suitable position to facilitate the replacing and maintenance work of the cutter.

[0027] It is noted that a spiral vane, a washing water device or the like for delivering cutting chips backward may be mounted on the boring head.

[0028] In the following, a description will be made of the case where the tunnel excavating process according to the present invention is carried out using the aforementioned tunnel excavator 1.

[0029] First, as shown in FIG. 2, the boring head 4 is moved forward by the pressing cylinder 5, the boring head 4 is pressed with given pressure against the base rocks 6, and the boring head 4 is rotated at the given rotational frequency and rotational torque to bore a pilot tunnel 7.

[0030] Subsequently, when the cutter head 2 is pressed against the working face of the base rocks 6 under the given pressure by means of the pressing mechanism, the roller cutter 3_{11} of the roller cutter group 3_1 at the foremost position in the excavating direction comes in contact with the neighborhood of the difference in level portion 6_1 of the base rocks 6 formed in the opening of the pilot tunnel 7, as shown in FIG. 3(A).

[0031] When the cutter head 2 is moved forward by the driving mechanism while being rotated at the given rotational frequency and rotational torque, difference in level portion 61 of the base rocks 6 is cut off in the direction of the pilot tunnel 7 by the cutter disk 3a of the roller cutter 3_{11}, as shown in FIG. 4, and a new difference in level portion 6_2 is formed at the rear of the cutter disk 3a.

[0032] Since the point of the roller cutter 3_{11} in contact with the base rocks is set in the vicinity of the difference in level portion 6_1 of the base rocks 6 as described above, the roller cutter 3_{11} acts against the tensile strength of the base rocks 6 to effect a so-called undercut which ruptures the difference in level portion 6_1 while cutting it off.

[0033] Generally, the tensile strength of the base rocks is far smaller than the compressive strength, say 1/10, and so, according to the undercut, the base rocks can be excavated under smaller pressure to enable reduction in wear of the roller cutter 3 as well as reduc-

tion in pressure resisting strength of the roller cutter 3.

[0034] If the cutter head 2 is further moved forward, a roller cutter 3_{21} of a roller cutter group 3_2 at a second position in an excavating direction comes in contact with the neighborhood of a difference in level portion 6_2 formed in the base rocks 6, as shown in FIG. 3 (B). Similarly, the difference in level portion 6_2 formed in the base rocks 6 is cut off in the direction of the pilot tunnel 7 by the cutter disk 3a of the roller cutter 3_{21} to form a new difference in level portion 6_3 at the rear of the cutter disk 3a, as shown in FIG. 3 (C).

[0035] Subsequently, as shown in FIG. 3 (D), the difference in level portion 6_3 is cut off in the direction of the pilot tunnel 7 by the cutter disk 3a of roller cutters 3_{31} and 3_{32} of a roller cutter group 3_3 at a third position in an excavating direction to form a new difference in level portion 6_4 at the rear of the cutter disk 3a. Thereafter, in a similar manner, a difference in level portion 6_{x+1} formed by roller cutters 3_{x1} and 3_{x2} of a forward roller cutter group 3_x is cut off by a roller cutter $3_{(x+1)Y}$ of a backward roller cutter group 3_{x+1} to form a new difference in level 6_{x+2}, as shown in FIG. 3 (E).

[0036] When a difference in level portion 6_7 is cut off in a direction of a pilot tunnel 7 by a cutter disk 3a of roller cutters 3_{71} and 3_{72} of a roller cutter group 3_7 at a final position in an excavating direction, as shown in FIG. 3 (F), the tunnel is then to be excavated while holding a working face which has a step-like section as shown in FIG. 3 (F).

[0037] As described above, a plurality of roller cutter groups 3_1, 3_2, 3_3 ... are arranged at given intervals in an excavating direction and in a direction vertical thereto, and a difference in level portion 6_x is cut off by the undercut by means of the roller cutters 3_{x1}, 3_{x2} ...belonging to the roller cutter group 3_x to thereby form a new difference in level 6_{x+1}. Therefore, the entire section can be excavated under pressure which is far smaller than the prior art, and the excavating performance of the tunnel excavator 1 can be rapidly enhanced.

[0038] Further, since the arrangement of the roller cutter groups 3_1, 3_2, 3_3 ... can be realized by making the cutter head 2 a substantially conical shape, the construction of the tunnel excavator 1 will not be specially complicated as compared with the prior art.

[0039] Moreover, by making the cutter head 2 a substantially conical shape, a further cubic construction is provided, which is rigid as compared with a conventional cutter head having a plane construction; a peripheral area is increased; and a taking-in opening for cutting chips can be made large so that the cutting chips can be discharged smoothly.

[0040] Alternatively, if a pilot tunnel has been bored in the base rocks 6, the boring head 4 is inserted into the pilot tunnel to enable the enlarging excavation using the former as a guide.

[0041] Further, by using direction-controlled boring which is very high in boring accuracy and high in cutting speed, a small-diameter pilot tunnel is first bored, and after this, the tunnel excavator 1 according to the present invention may be used to perform the efficient excavation.

[0042] While in the aforementioned tunnel excavator 1, the boring head 4 rotates independently of the cutter head 2, and is moved forward and backward about the center axis 0 of the cutter head 2, it is to be noted that as shown in FIG. 5, a boring head 8 may be secured to the cutter head 2 for rotation integral with the cutter head 2.

[0043] Further, while in the aforementioned tunnel excavator 1, the roller cutter 3 is inclined by a given angle θ with respect to the excavating direction, that is, the direction of the center axis 0, it can be made substantially parallel with the excavating direction as shown in FIG. 6. In this case, however, there is a possibility that the side resistance of the cutter disk 3a becomes high, and it is necessary that the roller cutters 3_{71}, 3_{72}, ... at least belonging to the roller cutter group 3_7 at a final position in an excavating direction are placed in an cantilever mode so as to prevent the cutter head 2 or the like from contacting the base rocks 6 to break the latter.

Claims

1. A tunnel excavating process characterized in that a plurality of roller cutter groups are arranged at given intervals in an excavating direction and in a direction vertical thereto, and points of the roller cutters in contact with base rocks belonging to the each roller cutter group are located in the vicinity of a difference in level portion formed in the base rocks to excavate the base rocks.

2. The tunnel excavating process according to claim 1, wherein the base rocks are excavated while boring an pilot tunnel.

3. A tunnel excavator characterized in that a plurality of roller cutter groups are arranged at given intervals in an excavating direction and in a direction vertical thereto on a cutter head having a substantially conical shape.

4. The tunnel excavator according to claim 3, wherein said given intervals in an excavating direction and in a direction vertical thereto are substantially constant.

5. The tunnel excavator according to claim 3 or 4, wherein a boring head is disposed coaxial with said cutter head.

6. The tunnel excavator according to claim 5, wherein said boring head rotates independently of said cutter head, and is moved forward and backward along a center axis of the cutter head.

7. The tunnel excavator according to claim 5, wherein said boring head is secured to said cutter head and rotates integral with the cutter head.

8. The tunnel excavator according to claims 3 to 7, wherein the roller cutters belonging to said roller cutter group are inclined by a given degree with respect to the excavating direction.

FIG. 1

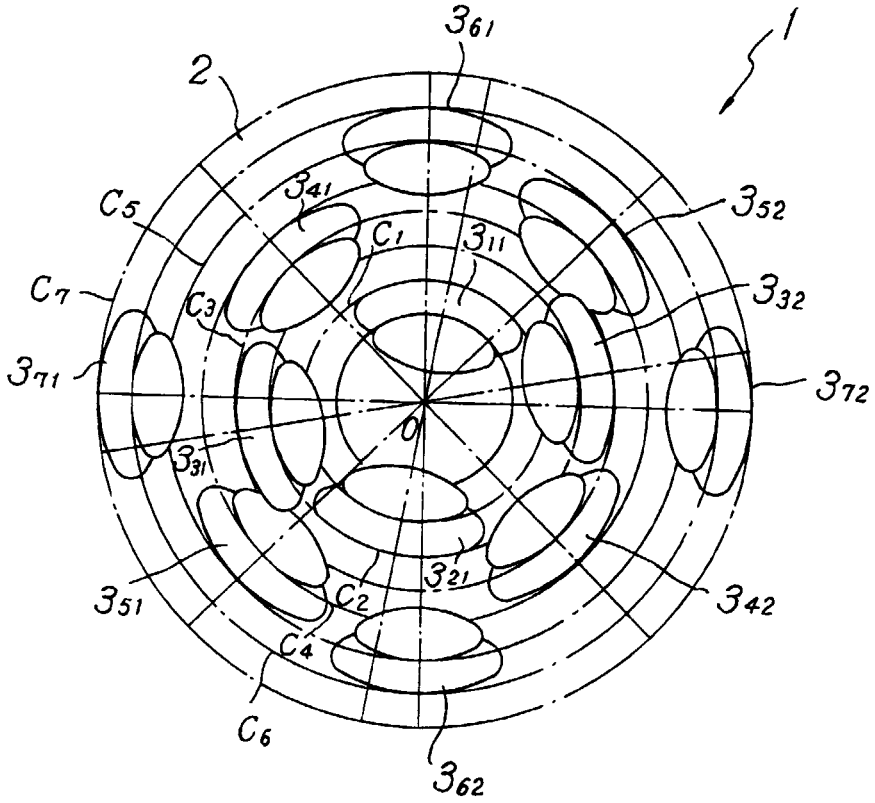
1
2
3_{61}
3_{41}
3_{52}
3_{11}
3_{32}
3_{72}
3_{71}
3_{31}
3_{21}
3_{51}
3_{42}
3_{62}
C_1
C_2
C_3
C_4
C_5
C_6
C_7
O

FIG. 2

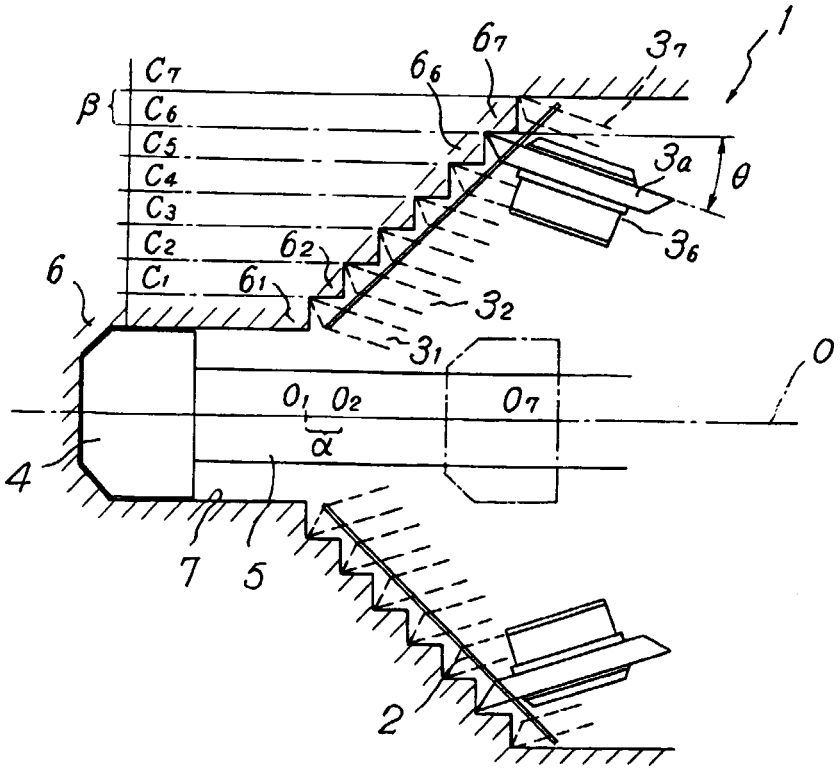
1
6_7
3_7
6_6
C_7
C_6
C_5
C_4
C_3
C_2
C_1
β
3_a
θ
3_6
6_2
6_1
6
3_2
3_1
O
O_1 O_2
O_7
α
4
7
5
2

FIG. 3

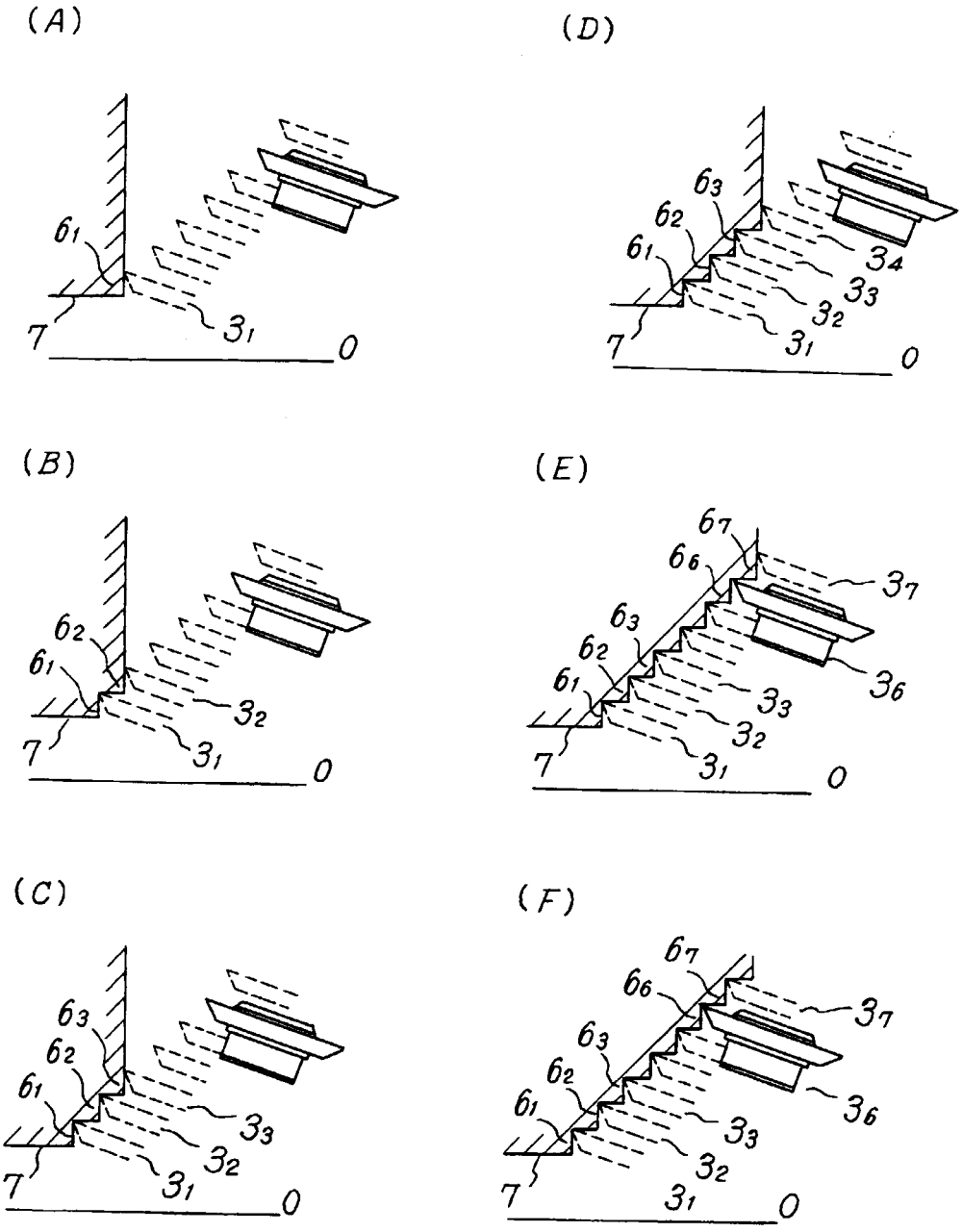

FIG. 4

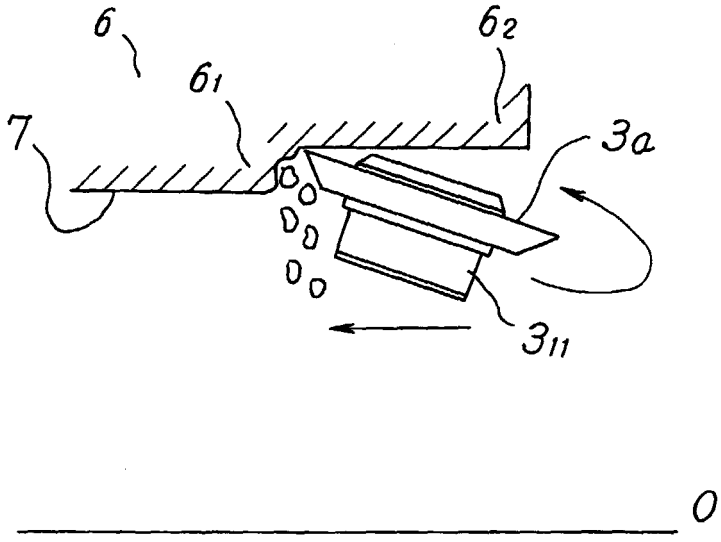

FIG. 5

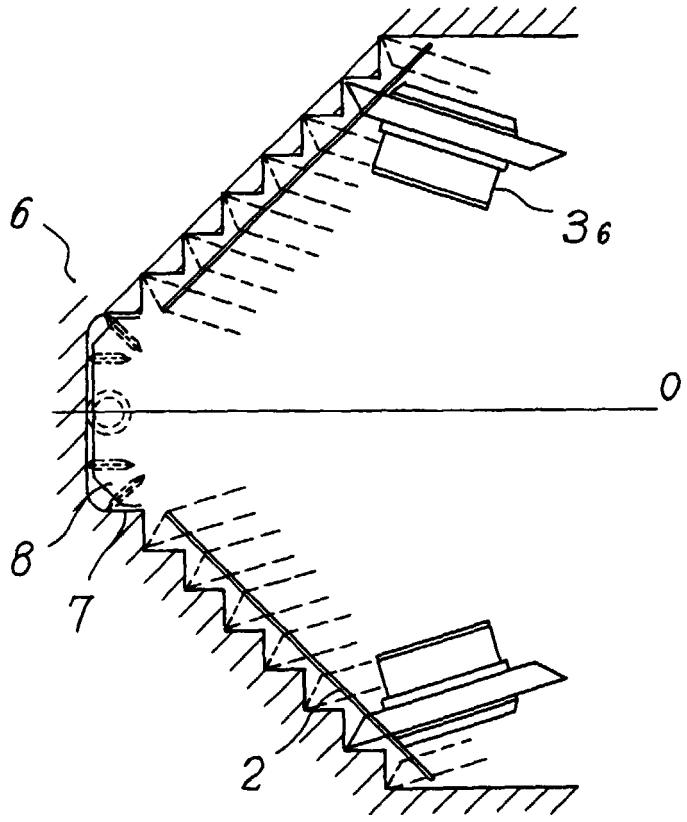

FIG. 6