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(54) **Lateral cutter system for boring holes**

(57) An underground boring machine (100), including a cutter device (102) configured to cut an underground construction, a base vehicle (104), and a rotating arm (106) comprising the cutter device (102), wherein the rotating arm (106) is configured to extend and retract, wherein the underground boring machine (100) is configured to cut a pre-defined geometry in the underground construction using the rotating arm (106) and the cutter device (102).

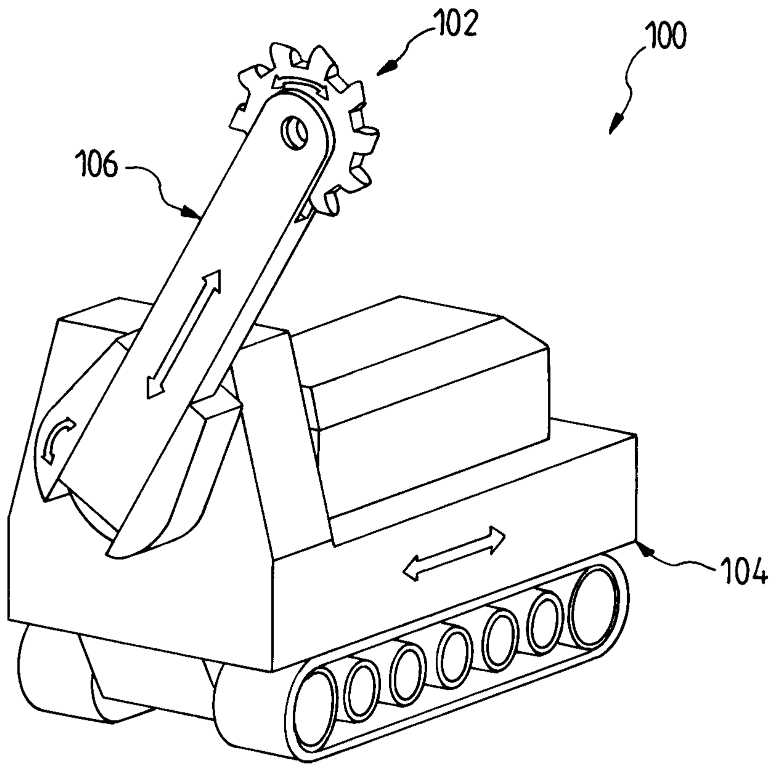

FIG.1

EP 1 760 256 A1

Description

Background

Field of the Invention

[0001] The invention relates generally to cutter systems for a boring hole.

Background Art

[0002] Boring holes are drilled using specialized underground boring machines. Generally a boring head of the underground boring machine is pressed against the tunnel front with large force at the same time as it is rotated. An example of such an underground boring machines is disclosed in the publication of the patent U.S. 5,104,262 to Forsberg et al. The particular feature of the underground boring machine disclosed in Forsberg is that it comprises a number of swingable arms provided with boring tools for the working of the tunnel wall outside its normal diameter. The borings tools are during boring retracted into the boring machine and protected by plates, which cover the larger part of the boring tools. When in use, the swingable arms are swung out and kept in swung out position for the working of the tunnel wall outside its normal diameter.

[0003] A further example of a underground boring machine is shown in the publication of the patent U.S. 5,529,437 to Filipowski et al. In addition to disclosing a boring head pressed against a tunnel front, Filipowski shows a laser based guidance system. The guidance system comprises a front part of the underground boring machine that reflects a laser beam emitted in a back part of the underground boring machine. Hence a direction of the front part's orientation may be determined relative to the back part of the underground boring machine.

[0004] Boring holes may be used to access distant locations, such as for example cavities, in geological formations. One possible application of a boring hole is to access an underground storage area for nuclear waste. In such an application, once the nuclear waste has been introduced into the underground storage area, it is desirable to close the boring hole with a concrete plug that is cast into a profiled section of the bore hole. Due to very high requirements on the quality of sealing, the profiled section of the bore hole must be prepared and cut with precision.

[0005] With nuclear waste disposal, a demolished zone forms along cut structure, bearing micro cracks caused by the relief of the compression of the rock. In this demolished zone, fluids may seep through the barrier into the main shaft of the nuclear storage. Thus, in some cases, it may also be desirable to refill a once cut area. However, with standard tunnel construction equipment, refilling a once cut area causes changes in the physical characteristic of the formation in the cut area.

Summary of Invention

[0006] In general, in one aspect, the invention relates to an underground boring machine, comprising a cutter device configured to cut an underground construction, a base vehicle, and a rotating arm comprising the cutter device, wherein the rotating arm is configured to extend and retract, wherein the underground boring machine is configured to cut a pre-defined geometry in the underground construction using the rotating arm and the cutter device.

[0007] In general, in one aspect, the invention relates to a method for cutting an underground construction, said underground construction extending longitudinally and having lateral walls, comprising determining a pre-defined geometry for said underground construction, positioning a cutter device inside the underground construction, wherein the cutter device is positioned in a longitudinal direction of the underground construction and in lateral directions along and beyond a circumference of the underground construction as defined by the lateral walls, issuing positioning coordinates associated with the pre-defined geometry inside the lateral wall along the circumference of the underground construction, and cutting the underground construction based on the pre-defined geometry.

[0008] Other aspects and advantages of the invention will be apparent from the following description and the appended claims.

Brief Description of Drawings

[0009] Figure 1 shows an underground boring machine in accordance with one embodiment of the invention.

[0010] Figure 2 shows an underground boring machine with sensor measurements in accordance with one embodiment of the invention.

[0011] Figure 3 shows a flow chart for using an underground boring machine in accordance with one embodiment of the invention.

[0012] Figures 4A-4C show underground geometries in accordance with one embodiment of the invention.

Detailed Description

[0013] One of the problems in preparing and cutting profiles in a boring hole in view of achieving an efficient sealing is the required accuracy of cutting. Embodiments of the invention relate to a underground boring machine capable of cutting 3D geometries precisely into any underground construction. Further, embodiments of the invention relate to a underground boring machine capable of refilling/sealing underground constructions to avoid fluid leakage.

[0014] Fig. 1 shows an underground boring machine (100) in accordance with one embodiment of the invention. In one embodiment of the invention, the underground boring machine includes a precisely steerable cutter (102) and is configured to cut 3D geometry into any underground construction, e.g., a tunnel, a mine shaft, a disposable cavern, etc. In one embodiment of the invention, the underground construction extends longitudinally and includes lateral walls. The underground boring machine (100) includes a base vehicle (104) running on chains, wheels, and rails, and a rotating arm (106) on the rear face. The arm (106) is equipped with a stone cutting device (102) (i.e., a cutter) configured to cut in a radial direction and an axial direction. The base vehicle (104) and the rotating arm (106) function as a positioning device that allows the underground boring machine to position the cutter device in a longitudinal direction of the underground construction and in lateral directions along and beyond a circumference of the underground construction as defined by the lateral walls of the underground construction.

[0015] In one embodiment of the invention, the cutting mechanisms used on the cutter (102) of the underground boring machine (100) may be a chain saw, a multi disc saw (i.e., with a number of diamond saw blades in a row), a milling head cutter, a single cutter, etc. Those skilled in the art will appreciate that the cutting mechanism may be changed during operation of the underground boring machine (100) to allow for the best possible cutting for a given shape.

[0016] Further, the rotating arm (106) is extendable/retractable during rotation. Thus, the arm (106) may be used to cut any geometry that is capable of being described using polar coordinates. Combining the arm with the main drive of the underground boring machine (100), any geometry describable in cylindrical coordinates may be cut. In one embodiment of the invention, the underground boring machine (100) is equipped with a computerized numerical control (CNC) to obtain precise geometries.

[0017] Figure 2 shows the underground boring machine (100) including sensor measurements in accordance with one embodiment of the invention. The sensors on the underground boring machine detect the position of the machine (*i.e.,* x-coordinate (202)), the rotation angle of the rotating arm (*i.e.,* φ-coordinate (204)), and the extension of the rotating arm (*i.e.,* R-coordinate (206)).

[0018] In one embodiment of the invention, sensors may be lasers pointing at a target area on the machine. The interference between the original laser beam and the reflected laser beam may then be used to obtain precision length measurements. For example, for the definition of the middle axis of the machine (*i.e.,* 208 shown in Figure 2), as long as the laser dot hits the target, the machine is on the correct path. Similarly, for the x-coordinate (202), an interferometer measurement may be used to determine the position of the machine. For the rotation of the arm, the φ-coordinate (204) may be calculated using an incremental angle measurement (i.e., an optical disc or magnetic disc) to trace the absolute angle of rotation of the arm. For the extension of the rotating arm, the R-coordinate (206) may be calculated using any analog or digital length measurement, such as a wire resistor, to trace the extension of the arm. Those skilled in the art will appreciate that sensors may be any computer controllable device, such as accelerometers.

[0019] Figure 3 shows a flow chart for using the underground boring machine to cut an underground construction, in accordance with one embodiment of the invention. Initially, a precise geometry is determined (Step 300). Specifically, the precise shape of how to cut the underground construction is pre-defined, prior to using the underground boring machine to cut the underground construction. Subsequently, a cutter device is positioned inside the underground construction (Step 302). In one embodiment of the invention, the cutter device is positioned in a longitudinal direction of the underground construction and in lateral directions along and beyond a circumference of the underground construction as defined by the lateral walls. In order to position the base vehicle and the cutter device in the underground construction, the CNC-control of the underground boring machine is used. Specifically, the sensors measuring the position of the base vehicle, the rotation angle of the arm of the underground boring machine, and the extension of the arm are used to exactly position the cutter device in the underground construction.

[0020] Next, positioning coordinates associated with the pre-defined geometry are issued to the cutter device (Step 304), so that the cutter device is able to cut the underground construction according to the precise pre-defined geometry desired (Step 306). For example, polar coordinates may be issued to the cutter device to enable the cutter device to cut the precise pre-defined geometry based on the polar coordinates.

[0021] As described above, one application of the underground boring machine of the present invention involves cutting channels in nuclear waste storages (i.e., tunnels, disposable caverns, mine shafts, etc.). A problem with nuclear waste storage is the formation of a demolished zone in the cut structure, which bears micro cracks caused by the relief of the compression of the rock. For example, when a tunnel is cut into an underground formation for nuclear waste storage, a border is created between the equalized stress level inside the formation and the zero stress level at the surface of the tunnel. The stress gradient relieves itself with the distance to the tunnel wall, creating cracks. The cracks form a pathway for fluids along the tunnel. Typically, the demolished zone is between 20 centimeters and 1.5 meters in depth, depending on the type of formation (i.e., granite, claystone, etc.). To seal this pathway, in one embodiment of the invention, channels (i.e., slots) are cut into the wall of the nuclear waste storage (e.g., a tunnel), which are deeper than the permeable demolished zone. In one embodiment of the invention, two channels are cut into the wall of the nuclear waste storage for redundancy. The channels may be filled with a material that forms an impermeable filter when exposed to liquid under differential pressure, such as bentonite, which expands when exposed to liquid and thus forms a seal. Those skilled in the art will appreciate that the present invention is used to cut the channels in the nuclear waste storage and to cut the entire inner contour of the underground geometry used as a nuclear waste storage.

[0022] Figs. 4A-4C show examples of underground geometries as a closure for a nuclear waste storage. Specifically, Fig. 4A shows the different shapes and geometries that the underground boring machine is capable of cutting. The rotating arm with variable length can describe any shape by combining the rotation angle (*i.e.,* φ_1 φ_2, φ_3, etc.) with the extension (*i.e.,* r_1, r_2, r_3).

[0023] The aforementioned measurements, combined with the position of the underground boring machine (*i.e.,* the x-coordinate) describe the whole structure using three coordinates, as shown in Fig. 4B. The geometry of the cutting structure shown in Fig. 4B may be used to create a barrier for fluids that may seep into the main shaft of the nuclear waste storage. To solve this problem, a deep trench may be cut circumferential around the tunnel to break through the demolished zone and fill the trench with a sealant. Further, the cutting structure profile includes a gradual increase in the tunnel diameter, followed by a sharp reduction in diameter. In one embodiment of the invention, this change in diameter provides a positive stop for a concrete or other plug to seal the tunnel, and is used to dissipate resulting stress from internal overpressure into the formation of the nuclear waste storage. In Fig. 4B, two such plug stops zones exist. Those skilled in the art will appreciate that other shapes shown in Fig. 4C may be necessary to build anchors to close the underground nuclear storage against possible pressure caused by the nuclear waste (i.e., to prevent the pressure from breaking through into the main shaft). The anchors are built such that they fit into their spacing very tightly to gain the maximum proofing from pressure caused by the nuclear waste. The labeled lines in Fig. 4B indicate where each anchor may be placed in one embodiment of the invention. For example, the first anchor shown in Fig. 4C (A-A) may be placed in the cross section A-A shown in Fig. 4B, the second anchor B-B of Fig. 4C may be placed in the cross section B-B of Fig. 4B, etc.

[0024] Those skilled in the art will appreciate that while Fig. 4B shows a horizontal cutting structure cut by the underground boring machine, a vertical cutting structure may also be cut using the underground boring machine. In order to cut a vertical structure, the sensors and position of the underground boring machine would have to be modified to guide the cutting of a vertical structure.

[0025] While the invention has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the attached claims.

Claims

1. An underground boring machine (100), comprising:

    a cutter device (102) configured to cut an underground construction;
    a base vehicle (104); and
    a rotating arm (106) comprising the cutter device (102), wherein the rotating arm (106) is configured to extend and retract,
    wherein the underground boring machine (100) is configured to cut a pre-defined geometry in the underground construction using the rotating arm (106) and the cutter device (102).

2. The underground boring machine according to claim 1, wherein the underground construction extends longitudinally and comprises lateral walls.

3. The underground boring machine according to claim 1, wherein the underground construction is at least one selected from the group consisting of a tunnel, a mine shaft, and a disposable cavern.

4. An underground boring machine according to claim 1, wherein the cutter device (102) is one selected from the group consisting of a stone cutting device, a chain saw type cutter, a circular blade cutter, and a milling head.

5. An underground boring machine according to claim 1, wherein the cutter device (102) is configured to cut in at least one selected from the group consisting of a radial direction and an axial direction.

6. An underground boring machine according to claim 1, wherein the pre-defined geometry is described in one selected from the group consisting of polar coordinates and cylindrical coordinates.

7. An underground boring machine according to claim 1, wherein the base vehicle (104) runs on chains, wheels and rails.

8. An underground boring machine according to claim 1, wherein the rotating arm (106) is mounted on the rear face side of the base vehicle (104).

9. An underground boring machine according to claim 1, wherein the underground boring machine (100) comprises a CNC-control comprising sensors for the position of the vehicle, the rotation angle of the arm, and the extension of the arm.

10. The underground boring machine according to claim 9, wherein the sensors comprise a laser pointing at a target area on the underground boring machine (100), and wherein the interference between an orig-

inal laser beam and a reflected laser beam is used to obtain high precision length measurements.

11. A method for cutting an underground construction, said underground construction extending longitudinally and having lateral walls, comprising:

determining a pre-defined geometry for said underground construction;
positioning a cutter device inside the underground construction, wherein the cutter device is positioned in a longitudinal direction of the underground construction and in lateral directions along and beyond a circumference of the underground construction as defined by the lateral walls;
issuing positioning coordinates associated with the pre-defined geometry inside the lateral wall along the circumference of the underground construction; and
cutting the underground construction based on the pre-defined geometry.

12. The method of claim 11, wherein the cutter device is one selected from the group consisting of a stone cutting device, a chain saw type cutter, a circular blade cutter, and a milling head.

13. The method of claim 11, wherein the cutter device is configured to cut in at least one selected from the group consisting of a radial direction and an axial direction.

14. The method of claim 11, wherein the pre-defined geometry is described in one selected from the group consisting of polar coordinates and cylindrical coordinates.

15. The method of claim 11, wherein positioning the cutter device inside the underground construction comprises using a CNC-control including sensors for the position of the vehicle, the rotation angle of the arm, and the extension of the arm.

16. The method of claim 15, wherein the sensors comprise a laser pointing at a target area on the underground boring machine, and wherein the interference between an original laser beam and a reflected laser beam is used to obtain high precision length measurements.

17. The method of claim 11, wherein the underground construction is at least one selected from the group consisting of a mine shaft, a tunnel, and a disposable cavern.

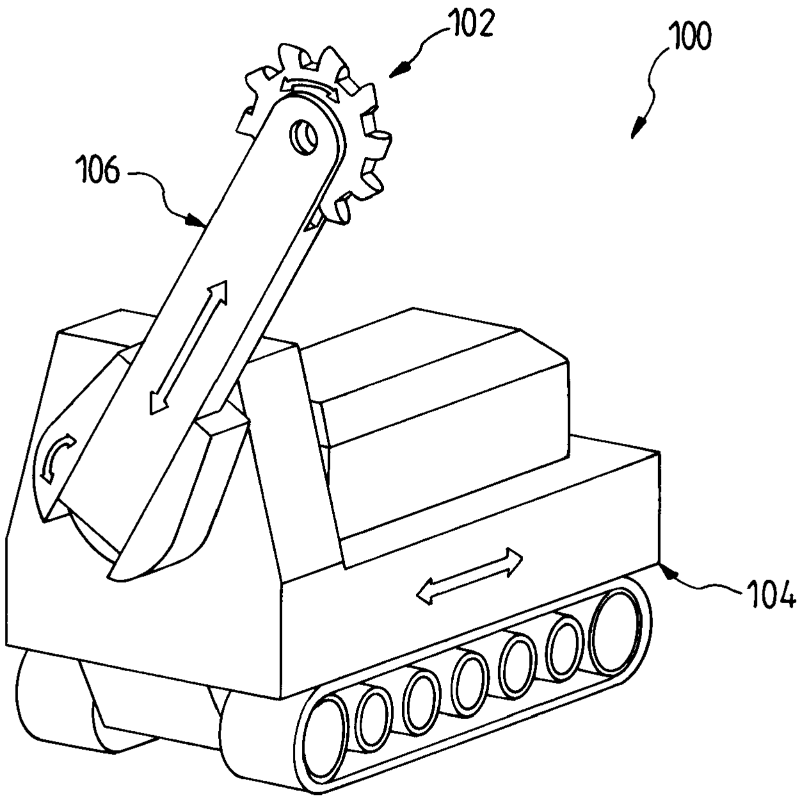

FIG.1

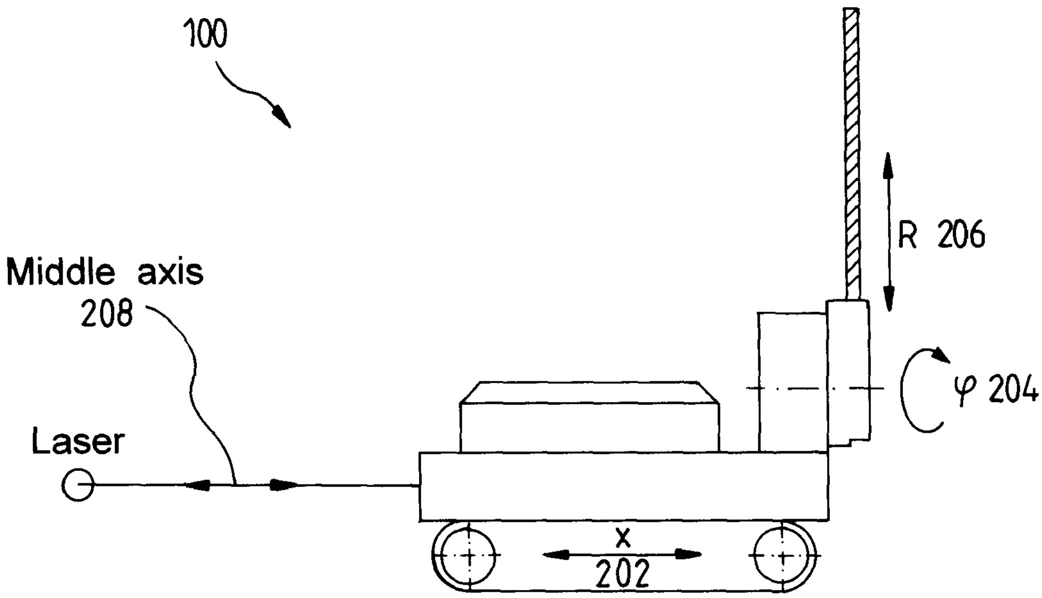

FIG.2

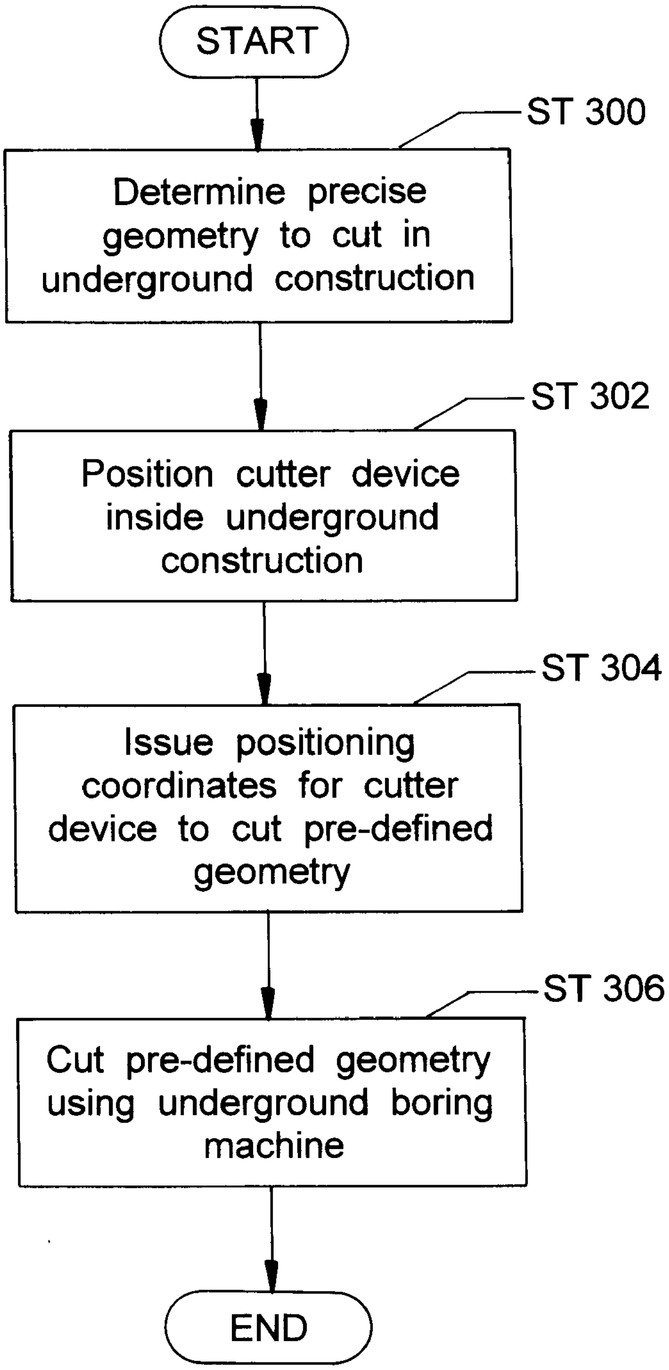
START
ST 300
Determine precise geometry to cut in underground construction
ST 302
Position cutter device inside underground construction
ST 304
Issue positioning coordinates for cutter device to cut pre-defined geometry
ST 306
Cut pre-defined geometry using underground boring machine
END

FIG.3

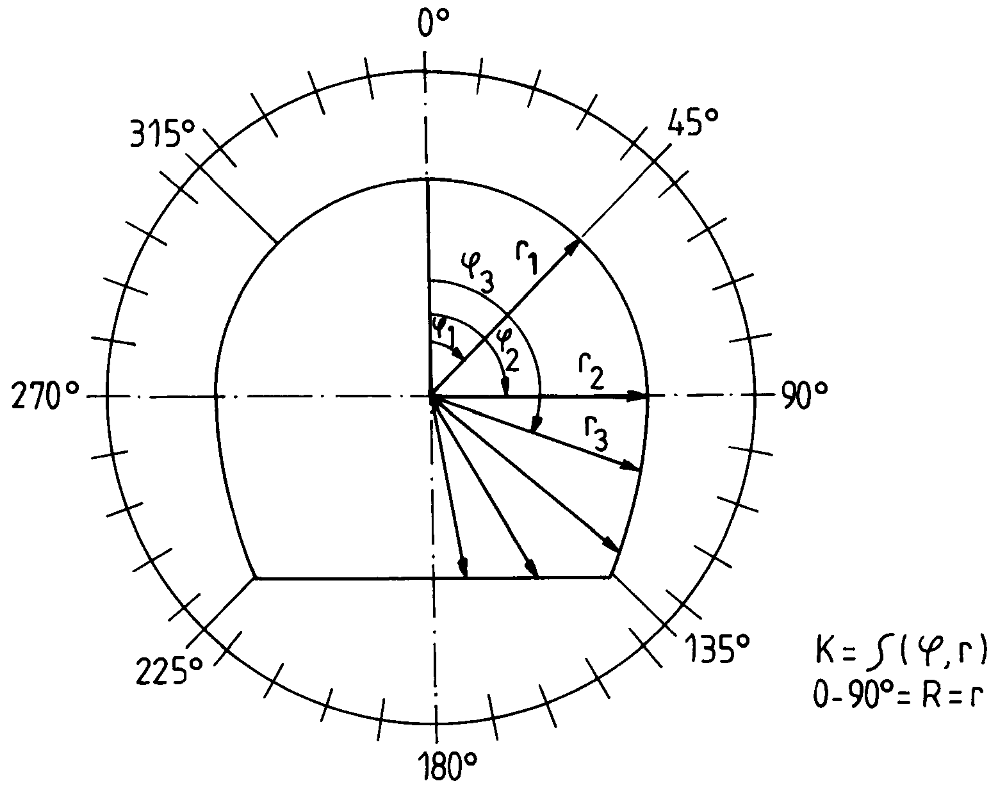

FIG.4A

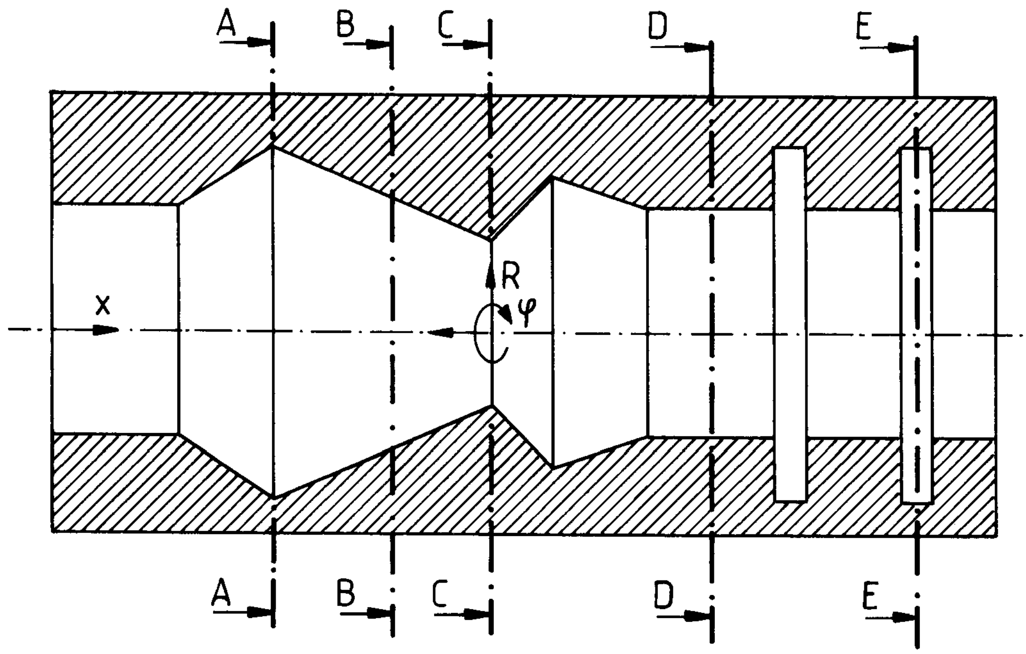

FIG.4B

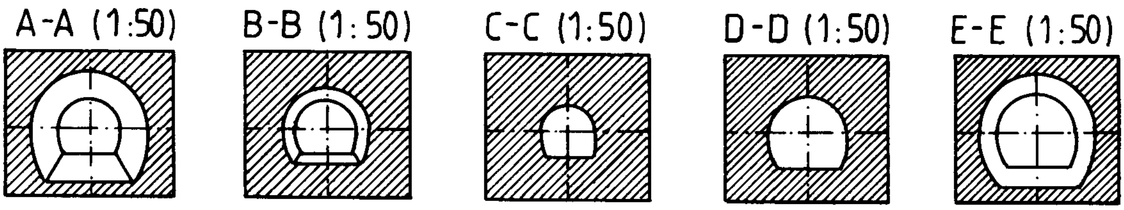

FIG.4C

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EUROPEAN SEARCH REPORT

Application Number
EP 05 10 7606

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	23 January 2007	Ott, Stéphane

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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