

DESCRIPTION

Title of Invention: TUNNEL BORING MACHINE

Technical Field

[0001] The present invention relates to a tunnel boring machine.

Background Art

[0002] In a tunnel boring machine, a cutter head is rotatably supported by a boring machine main body via an annular cutter drum. For example, Patent Literature 1 discloses a tunnel boring machine configured to allow the worker to enter a cutter drum.

[0003] Specifically, in the tunnel boring machine disclosed in Patent Literature 1, the boring machine main body includes an inner peripheral wall facing an inner wall portion of the cutter drum and an outer peripheral wall facing an outer wall portion of the cutter drum, and each of the inner peripheral wall of the boring machine main body and the inner wall portion of the cutter drum is provided with an opening. Thus, the worker can enter the cutter drum from inside the inner peripheral wall of the boring machine main body through the openings.

[0004] Further, in the tunnel boring machine disclosed in Patent Literature 1, the opening provided in the inner wall portion of the cutter drum is normally closed by a door. The door is fixed to the inner wall portion of the cutter drum by bolts.

Citation List

Patent Literature

[0005] PTL 1: Japanese Laid-Open Patent Application Publication No. 2018-141278

Summary of Invention

Technical Problem

[0006] In the structure in which the door is fixed to the inner wall portion of the cutter drum by bolts, the bolts could be dropped between the inner wall portion of the cutter drum and the inner peripheral wall of the boring machine main body when removed. In this case, the dropped bolts could adversely affect a slewing bearing for the cutter drum.

[0007] In some cases, the outer wall portion of the cutter drum is provided with the opening for entry into the cutter drum. In such a case, as in the above case, the bolts for fixing the door could be dropped between the outer wall portion of the cutter drum and the outer peripheral wall of the boring machine main body.

[0008] It is therefore an object of the present invention to provide a tunnel boring machine

that can prevent dropping of bolts for fixing a door that closes an opening provided in a cutter drum.

Solution to Problem

[0009] In order to solve the above problem, a tunnel boring machine of the present invention includes: an annular cutter drum that rotates together with a cutter head, the cutter drum including an inner wall portion and an outer wall portion, the inner or outer wall portion being provided with an opening for entry into the cutter drum; and a door that is fixed to the inner or outer wall portion by a closure bolt in a state where the door closes the opening, wherein the closure bolt includes a head and a shaft, the shaft having a tip on which a thread that is screwed into a tapped hole provided in the door is formed, the shaft being provided with a small diameter portion having a diameter smaller than an outer diameter of the thread, the small diameter portion being closer to the head than the thread, and the inner or outer wall portion is provided with a tapped hole into which the small diameter portion of the shaft of the closure bolt is inserted and into which the thread is screwable.

[0010] In the above configuration, the opening provided in the inner or outer wall portion of the cutter drum can be opened by unscrewing the thread of the closure bolt from the tapped hole of the door. At this time, since the inner or outer wall portion of the cutter drum is provided with the tapped hole into which the small diameter portion of the closure bolt is inserted and into which the thread of the closure bolt is screwable, the tapped hole functions as a retainer for the closure bolt. Thus, dropping of the closure bolt can be prevented.

Advantageous Effects of Invention

[0011] The present invention can prevent dropping of a closure bolt for fixing a door that closes an opening provided in a cutter drum.

Brief Description of Drawings

[0012] FIG. 1 is a cross-sectional view of a tunnel boring machine according to one embodiment of the present invention.

FIG. 2 is a front view of the tunnel boring machine shown in FIG. 1.

FIG. 3 is a cross-sectional view taken along the line III-III of FIG. 1.

FIG. 4 is a cross-sectional view taken along the line IV-IV of FIG. 3.

FIG. 5 is an enlarged view of key parts shown in FIG. 3.

FIG. 6 shows a part of a cutter drum as viewed from inside.

FIG. 7 is a cross-sectional view taken along the line VII-VII of FIG. 6.

FIG. 8 is a cross-sectional view taken along the line VIII-VIII of FIG. 6.

FIG. 9 is a cross-sectional view taken along the line IX-IX of FIG. 6.

FIG. 10 is a cross-sectional view taken along the line X-X of FIG. 6.

Description of Embodiments

[0013] FIGS. 1 and 2 show a tunnel boring machine 1 according to one embodiment of the present invention. For example, the tunnel boring machine 1 is a shield machine inside which segments are assembled. The present invention is applicable to tunnel boring machines other than shield machines.

[0014] Specifically, the tunnel boring machine 1 includes a cutter head 3 that digs the ground and a boring machine main body 2 rotatably supporting the cutter head 3 via a cutter drum 5. That is, the cutter drum 5 rotates together with the cutter head 3.

[0015] In the present embodiment, the cross-section of the tunnel boring machine 1 has a circular shape. The cross-section of the tunnel boring machine 1 may have another shape such as a rectangular shape. In the following description, for convenience of illustration, the advancing direction of the tunnel boring machine 1 is defined as a forward direction, and the opposite direction is defined as a rearward direction.

[0016] The boring machine main body 2 includes a tubular barrel 21 and a bulkhead 22 closing a front opening of the barrel 21. The bulkhead 22 faces the cutter head 3, and a cutter chamber 10 is formed between the bulkhead 22 and the cutter head 3.

[0017] The cutter head 3 includes radially-arranged cutter spokes 31 (12 cutter spokes 31 in the example shown). That is, each cutter spoke 31 extends in the radial direction of the cutter head 3 (i.e., along a line passing through the rotational center of the cutter head 3). The cutter spokes 31 adjacent to each other are coupled by a reinforcement 32.

[0018] Each cutter spoke 31 has a rectangular cross-sectional shape. Cutter bits 3a are mounted on the front surface of each cutter spoke 31, and cutter bits 3b are mounted on the side surfaces of each cutter spoke 31.

[0019] Roller cutters may be mounted on the cutter spokes 31 instead of the cutter bits 3a and 3b. Alternatively, both the cutter bits and roller cutters may be mounted on the cutter spokes 31. The cutter head 3 need not include the cutter spokes 31 and may be disc-shaped.

[0020] The cutter drum 5 is annular and located behind the cutter head 3. Coupling posts 33, the number of which is equal to the number of the cutter spokes 31, are located between the cutter head 3 and the cutter drum 5, and each cutter spoke 31 is coupled to the cutter drum 5 by a

corresponding one of the coupling posts 33.

[0021] The cutter drum 5 is disposed in such a manner as to divide the bulkhead 22 into a ring-shaped outer bulkhead 22a and a disc-shaped inner bulkhead 22b. An outer peripheral wall 23 facing the outer peripheral surface (outer wall portion 54 described later) of the cutter drum 5 extends from the inner periphery of the outer bulkhead 22a, and the gap between the outer peripheral wall 23 and the outer peripheral surface of the cutter drum 5 is sealed with soil seals (not shown). Likewise, an inner peripheral wall 24 facing the inner peripheral surface (inner wall portion 53 described later) of the cutter drum 5 extends from the outer periphery of the inner bulkhead 22b, and the gap between the inner peripheral wall 24 and the inner peripheral surface of the cutter drum 5 is sealed with soil seals (not shown).

[0022] The central portion of the cutter head 3 is connected to the central portion of the inner bulkhead 22b by a rotary joint 34. The rotary joint 34 is hollow, and pipes etc. can be arranged in the interior of the rotary joint 34.

[0023] All of the cutter spokes 31, the coupling posts 33, and the cutter drum 5 are hollow, and the worker can perform works inside the cutter spokes 31, the coupling posts 33, and the cutter drum 5. In the present embodiment, the worker can enter any of the cutter spokes 31 from inside the inner peripheral wall 24 through the interior of the cutter drum 5 and the interior of a corresponding one of the coupling posts 33.

[0024] More specifically, as shown in FIG. 3, the inner peripheral wall 24 is provided with vertically long openings 25 located to the left and right of the rotational center of the cutter drum 5. As shown in FIG. 5, each opening is covered by an enclosure 26 together with a portion of the space inside the inner peripheral wall 24, and the enclosure 26 is provided with a door 27.

[0025] Referring back to FIG. 3, workspaces 50, the number of which is equal to the number of the cutter spokes 31, are formed in the cutter drum 5. The workspaces 50 are formed at locations where the cutter spokes 31 cross the cutter drum 5 when viewed in the forward/rearward direction.

[0026] In the cutter drum 5, each workspace 50 is bounded by a pair of dividing plates 56 in the circumferential direction of the cutter drum 5. The pair of dividing plates 56 are parallel to each other. In the case where one of the workspaces 50 is located directly lateral to the rotational center of the cutter drum 5, the lower dividing plate 56 facing the workspace 50 functions as a working platform.

[0027] More specifically, as shown in FIG. 4, the cutter drum 5 includes a front wall portion 51, a rear wall portion 52, an inner wall portion 53, and an outer wall portion 54. Each dividing plate 56 is joined to the front, rear, inner, and outer wall portions 51, 52, 53, and 54.

[0028] In the cutter drum 5, reinforcing plates 55 are disposed between the workspaces 50. Each reinforcing plate 55 is also joined to the front, rear, inner, and outer wall portions 51, 52, 53, and 54.

[0029] The inner wall portion 53 is provided with openings 5a for entry into the workspaces 50, the openings 5a being located in correspondence with the workspaces 50. The openings 5a are toward the rear of the inner wall portion 53 in the forward/rearward direction so that each opening 5a can be brought into alignment with the opening 25 of the inner peripheral wall 24.

[0030] The front wall portion 51 is provided with openings 5b located in correspondence with the workspaces 50. Each opening 5b serves to allow a corresponding one of the workspaces 50 to communicate with the interior of a corresponding one of the coupling posts 33.

[0031] Hereinafter, doors 7 that close the openings 5a and components neighboring the doors 7 will be described with reference to FIGS. 6 to 8. In FIGS. 3 to 5, the doors 7 and the neighboring components are omitted for simplicity of the figures.

[0032] In the present embodiment, each door 7 closes a corresponding one of the openings 5a in a state where the door 7 is fitted in the opening 5a. The doors 7 are not limited to this configuration and can be modified as appropriate.

[0033] More specifically, the inner wall portion 53 includes a pair of transverse frames 41 and 42 spaced from each other across the opening 5a in the circumferential direction of the cutter drum 5 (upward/downward direction in FIG. 6) and a pair of longitudinal frames 43 and 44 spaced from each other across the opening 5a in the axial direction of the cutter drum 5 (leftward/rightward direction in FIG. 6).

[0034] The door 7 includes a main plate 71 having substantially the same size as the opening 5a, a pair of transverse frames 73 and 74, and a pair of longitudinal frame 75 and 76, the transverse and longitudinal frames 73, 74, 75, and 76 surrounding the main plate 71. The transverse frames 73 and 74 contact with the back sides (outer sides in the radial direction of the cutter drum 5) of the transverse frames 41 and 42 of the inner wall portion 53, respectively, and the longitudinal frames 75 and 76 contact with the back sides (outer sides in the radial direction of the cutter drum 5) of the longitudinal frames 43 and 44, respectively.

[0035] The door 7 further includes a jacket 72 that is in face-to-face contact with the main plate 71 and that is fitted into the opening 5a. The jacket 72 is provided with a circular hole 72a located at the center of the jacket 72, and the central portion of the main plate 71 is visible through the circular hole 72a.

[0036] The door 7 is fixed to the inner wall portion 53 by closure bolts 6 in a state where the door 7 closes the opening 5a. In the present embodiment, as shown in FIG. 9, each of the

transverse frames 41 and 42 is provided with two through holes 45 for insertion of the closure bolts 6. Alternatively, the longitudinal frames 43 and 44 may be provided with the through holes 45.

[0037] Each closure bolt 6 includes a first head 61 and a first shaft 62. The first head 61 is provided with a hexagon socket for rotation of the closure bolt 6.

[0038] Each of the transverse frames 73 and 74 of the door 7 is provided with tapped holes 78 located in correspondence with the through holes 45. The first shaft 62 of the closure bolt 6 has a tip on which a first thread 63 that is screwed into the tapped hole 78 is formed. The first shaft 62 is provided with a first small diameter portion 64 having a diameter smaller than the outer diameter of the first thread 63, the first small diameter portion 64 being closer to the first head 61 than the first thread 63.

[0039] Each through hole 45 includes a large diameter portion 46 having a larger diameter than the first head 61 of the closure bolt 6 and a small diameter portion 47 having a smaller diameter than the first head 61. The region of the small diameter portion 47 that is contiguous to the large diameter portion 46 is a tapped hole 48 into which the first thread 63 is screwable. The first small diameter portion 64 of the first shaft 62 is inserted into the tapped hole 48.

[0040] That is, to insert the closure bolt 6 into the through hole 45, the first thread 63 is screwed into the tapped hole 48, and the closure bolt 6 is rotated until the first thread 63 passes through the tapped hole 48. This creates a state where the first small diameter portion 64 of the first shaft 62 has been inserted into the tapped hole 48.

[0041] Referring back to FIGS. 6 to 8, a sliding board 9 slidable in the axial direction of the cutter drum 5 is disposed in the workspace 50. The door 7 is mounted to the sliding board 9.

[0042] The sliding board 9 includes a main plate 91 parallel to the main plate 71 of the door 7 and a cylindrical block 92 located at the center of the main plate 91. Two rollers 93 are located respectively at both ends of the main plate 91 in the circumferential direction of the cutter drum 5.

[0043] Rails 11 extending in the axial direction of the cutter drum 5 are mounted via support bases 12 to the two dividing plates 56 located on both sides of the workspace 50. The rollers 93 engage with the rails 11 and roll along the rails 11.

[0044] The main plate 71 of the door 7 is provided with four rods 95 perpendicular to the main plate 71. The number of the rods 95 can be changed as appropriate. Each rod 95 is held by the main plate 91 of the sliding board 9 so as to be slidable in the axial direction of the rod 95. That is, the door 7 is movable toward the sliding board 9 (outward in the radial direction of the cutter drum 5) and away from the sliding board 9 (inward in the radial direction of the cutter

drum 5) by being guided by the rods 95.

[0045] The door 7 is fixed to the sliding board 9 by an opening bolt 8 in a state where the opening 5a is open. The main plate 71 of the door 7 is provided with a ring 77 located at the center of the main plate 71 to hold the opening bolt 8.

[0046] More specifically, as shown in FIG. 10, the opening bolt 8 includes a second head 81 and a second shaft 82. In the present embodiment, the second head 81 has a hexagonal outline. Alternatively, the second head 81 may have a circular outline and be provided with a hexagon socket.

[0047] The block 92 of the sliding board 9 described above is provided with a tapped hole 94 located in correspondence with the central hole of the ring 77 of the door 7. The second shaft 82 of the opening bolt 8 has a tip on which a second thread 83 that is screwed into the tapped hole 94 is formed. The second shaft 82 is provided with a second small diameter portion 84 having a diameter smaller than the outer diameter of the second thread 83, the second small diameter portion 84 being closer to the second head 81 than the second thread 83. A third thread 85 is formed on the second shaft 82, the third thread 85 having the same outer diameter as the second thread 83 and being located between the second head 81 and the second small diameter portion 84.

[0048] That region of the ring 77 of the door 7 which faces the sliding board 9 is provided with a tapped hole 79 into which the second thread 83 is screwable. The third thread 85 is screwed into the tapped hole 79.

[0049] To open the opening 5a, first, the closure bolts 6 are rotated to unscrew the first threads 63 from the tapped holes 78 of the door 7. Subsequently, the opening bolt 8 is rotated to unscrew the third thread 85 from the tapped hole 79 of the door 7 and create a state where the second small diameter portions 84 of the second shafts 82 has been inserted into the tapped hole 79. After that, the door 7 is pushed into the workspace 50, and the ring 77 of the door is brought into contact with the block 92 of the sliding board 9 while the opening bolt 8 is rotated to screw the second thread 83 into the tapped hole 94 of the sliding board 9.

[0050] In the tunnel boring machine 1 of the present embodiment, as described above, the opening 5a provided in the inner wall portion 53 of the cutter drum 5 can be opened by unscrewing the first threads 63 of the closure bolts 6 from the tapped holes 78 of the door 7. At this time, since the inner wall portion 53 of the cutter drum 5 is provided with the tapped holes 48 into which the first small diameter portions 64 of the closure bolts 6 are inserted and into which the first threads 63 of the closure bolts 6 are screwable, the tapped holes 48 (to be precise, the threads of the tapped holes 48) function as retainers for the closure bolts 6. Thus, dropping

of the closure bolts 6 can be prevented.

[0051] Further, in the present embodiment, since the portion of the door 7 into which the opening bolt 8 is inserted is provided with the tapped hole 79, the tapped hole 79 (to be precise, the thread of the tapped hole 79) functions as a retainer for the opening bolt 8. Thus, not only dropping of the closure bolts 6 but also dropping of the opening bolt 8 can be prevented.

[0052] (Modifications)

The present invention is not limited to the embodiment described above, and various modifications can be made without departing from the gist of the present invention.

[0053] For example, unlike in the above embodiment, the worker may enter any of the cutter spokes 31 from outside the outer peripheral wall 23 through the interior of the cutter drum 5 and the interior of a corresponding one of the coupling posts 33. In this case, the outer wall portion 54 of the cutter drum 5 is provided with the openings 5a for entry into the cutter drum 5 and provided with the tapped holes 48. That is, the door 7 is fixed to the outer wall portion 54 by the closure bolts 6 in a state where the door 7 closes the opening 5a.

[0054] The third thread 85 need not be formed on the second shaft 82 of the opening bolt 8, and the second small diameter portion 84 may extend from the second thread 83 to the second head 81. In this case, the second small diameter portion 84 is inserted into the tapped hole 79. However, in the case where the third thread 85 is formed on the second shaft 82 as in the above embodiment, the opening bolt 8 can be fixed to the door 7 by screwing the third thread 85 of the opening bolt 8 into the tapped hole 79 provided in the door 7 in a state where the door 7 closes the opening 5a.

[0055] The rods 95 may be omitted, and the worker may lift the door 7 and bring the door 7 into contact with the sliding board 9 to open the opening 5a. However, in the case where the door 7 is provided with the rods 95 as in the above embodiment, the opening 5a can be closed or opened simply by moving the door 7 in the axial direction of the rods 95.

[0056] Alternatively, the sliding board 9 may be omitted, and the door 7 may be hinged and pivotally supported by the cutter drum 5.

[0057] (Summary)

A tunnel boring machine of the present invention includes: an annular cutter drum that rotates together with a cutter head, the cutter drum including an inner wall portion and an outer wall portion, the inner or outer wall portion being provided with an opening for entry into the cutter drum; and a door that is fixed to the inner or outer wall portion by a closure bolt in a state where the door closes the opening, wherein the closure bolt includes a head and a shaft, the shaft having a tip on which a thread that is screwed into a tapped hole provided in the door is

formed, the shaft being provided with a small diameter portion having a diameter smaller than an outer diameter of the thread, the small diameter portion being closer to the head than the thread, and the inner or outer wall portion is provided with a tapped hole into which the small diameter portion of the shaft of the closure bolt is inserted and into which the thread is screwable.

[0058] In the above configuration, the opening provided in the inner or outer wall portion of the cutter drum can be opened by unscrewing the thread of the closure bolt from the tapped hole of the door. At this time, since the inner or outer wall portion of the cutter drum is provided with the tapped hole into which the small diameter portion of the closure bolt is inserted and into which the thread of the closure bolt is screwable, the tapped hole functions as a retainer for the closure bolt. Thus, dropping of the closure bolt can be prevented.

[0059] The head, the shaft, the thread, and the small diameter portion of the closure bolt may be a first head, a first shaft, a first thread, and a first small diameter portion, respectively, the tunnel boring machine may further include a sliding board disposed inside the cutter drum and slidable in an axial direction of the cutter drum, the door may be fixed to the sliding board by an opening bolt in a state where the opening is open, the opening bolt may include a second head and a second shaft, the second shaft having a tip on which a second thread that is screwed into a tapped hole of the sliding board is formed, the second shaft being provided with a second small diameter portion having a diameter smaller than an outer diameter of the second thread, the second small diameter portion being closer to the second head than the second thread, and the door may be provided with a tapped hole into which the second thread is screwable. In this configuration, the tapped hole of the door functions as a retainer for the opening bolt. Thus, not only dropping of the closure bolt but also dropping of the opening bolt can be prevented.

[0060] The door may be provided with a rod penetrating the sliding board, and the rod may be held by the sliding board so as to be slidable in an axial direction of the rod. In this configuration, the opening can be closed or opened simply by moving the door in the axial direction of the rod.

[0061] A third thread that is screwed into the tapped hole of the door may be formed on the second shaft of the opening bolt, the third thread being located between the second head and the second small diameter portion. In this configuration, the opening bolt can be fixed to the door by screwing the third thread of the opening bolt into the tapped hole provided in the door in a state where the door closes the opening.

Reference Signs List

[0062] 1 tunnel boring machine

3	cutter head
5	cutter drum
5a	opening
48	tapped hole
53	inner wall portion
54	outer wall portion
6	closure bolt
61	first head
62	first shaft
63	first thread
64	first small diameter portion
7	door
78, 79	tapped hole
8	opening bolt
81	second head
82	second shaft
83	second thread
84	second small diameter portion
85	third thread
9	sliding board
94	tapped hole
95	rod

CLAIMS

1. A tunnel boring machine comprising:
 - an annular cutter drum that rotates together with a cutter head, the cutter drum including an inner wall portion and an outer wall portion, the inner or outer wall portion being provided with an opening for entry into the cutter drum; and
 - a door that is fixed to the inner or outer wall portion by a closure bolt in a state where the door closes the opening, wherein
 - the closure bolt includes a head and a shaft, the shaft having a tip on which a thread that is screwed into a tapped hole provided in the door is formed, the shaft being provided with a small diameter portion having a diameter smaller than an outer diameter of the thread, the small diameter portion being closer to the head than the thread, and
 - the inner or outer wall portion is provided with a tapped hole into which the small diameter portion of the shaft of the closure bolt is inserted and into which the thread is screwable.
2. The tunnel boring machine according to claim 1, wherein
 - the head, the shaft, the thread, and the small diameter portion of the closure bolt are a first head, a first shaft, a first thread, and a first small diameter portion, respectively,
 - the tunnel boring machine further comprises a sliding board disposed inside the cutter drum and slidable in an axial direction of the cutter drum,
 - the door is fixed to the sliding board by an opening bolt in a state where the opening is open,
 - the opening bolt includes a second head and a second shaft, the second shaft having a tip on which a second thread that is screwed into a tapped hole provided in the sliding board is formed, the second shaft being provided with a second small diameter portion having a diameter smaller than an outer diameter of the second thread, the second small diameter portion being closer to the second head than the second thread, and
 - the door is provided with a tapped hole into which the second thread is screwable.
3. The tunnel boring machine according to claim 2, wherein
 - the door is provided with a rod penetrating the sliding board, and
 - the rod is held by the sliding board so as to be slidable in an axial direction of the rod.

4. The tunnel boring machine according to claim 2 or 3, wherein a third thread that is screwed into the tapped hole provided in the door is formed on the second shaft of the opening bolt, the third thread being located between the second head and the second small diameter portion.