

CUTTER HEAD FOR EXCAVATION EQUIPMENT AND EXCAVATION EQUIPMENT HAVING THE SAME

FIELD

[0001] The present disclosure relates to the technical field of underground engineering, and
5 specifically to a cutter head for an excavation equipment and an excavation equipment having
the same.

BACKGROUND

[0002] According to the *Code for Design of Metro*, a cross passage should be provided
between two single-track tunnels when the tunnel extension length is greater than 600m.
10 Mining method is employed for most of the cross passages of subway tunnels and municipal
highway tunnels. For example, in an area where the groundwater is abundant, soil is usually
reinforced using a ground-freezing method, and then the mining method is used for the
excavation of the cross passage. However, the ground-freezing method is easy to lead to
adverse consequences such as frost heave and immersion, which will usually cause a certain
15 surface subsidence and even collapse when the surface subsidence is serious. It is especially
difficult for the mining method to adapt to a central urban district with complex geological
conditions and high environmental protection requirements. Furthermore, the mining method
requires a long construction period, during which usually more than 100 days of freezing are
required before excavation begins, so that the construction period often lasts as long as 4-6
20 months. In addition, the ground-freezing method does not work well for the formation with
sand layer and confined water, and it is prone to accident is prone to occur, high environmental
impact and high risk.

[0003] In recent years, the use of modular cross passage structure combined with mechanical
excavation of cross passage has been proposed. Therefore, cutting operation on the segment
25 of main tunnel using excavation equipment is necessary. Upon the cutting operation, it is
desirable that the excavation equipment first contacts the segment at a position approximately
at a center of the cross passage, and the cutting trajectory spreads from the center to the
circumference. The segment corresponding to a radially outer side of the cross passage is
finally cut. Conventional excavation equipment is mostly suitable for cutting a planar work
30 surface. When the conventional excavation equipment is used for cutting, the segment of the
main tunnel firstly contacts the excavation equipment at the portion corresponding to the

radially outer side of the cross passage, due to the arc-shaped structure of the segment. This portion will be firstly cut, which may lead to forward collapse of an intermediate portion of the segment.

[0004] In addition, the mechanical method for cross passage construction is usually implemented in a soft soil region at present. As the mechanical method for cross passage construction is promoted in different regions, the excavation equipment faces more complex geological conditions. For example, it is difficult for the conventional excavation equipment to provide satisfactory cutting effects in hard rock regions, and abrasion is serious.

[0005] Therefore, it is desirable to provide an improved excavation equipment which is adapted to cutting operations during the construction of the cross passage using the mechanical method under different geological conditions.

SUMMARY

[0006] An object of the present disclosure is to provide a cutter head of an excavation equipment adapted to cutting operations on a main tunnel segment during construction of a cross passage using mechanical method.

[0007] According to an aspect of the present application, the cutter head comprises:

[0008] a base rotatable about a rotation axis in an excavation direction of the excavation equipment; and

[0009] cutters mounted on the base, the cutters comprising a plurality of radial rolling cutter sets spaced-apart in a circumferential direction defined relative to the rotation axis, each of the radial rolling cutter sets comprising a plurality of radial rolling cutters arranged radially starting from the rotation axis in a radial direction defined relative to the rotation axis;

[0010] wherein, in each radial rolling cutter set, each radial rolling cutter is rotatable about a radial rolling cutter rotation axis perpendicular to the rotation axis, and each radial rolling cutter is arranged to be backward by a predetermined distance in the excavation direction relative to an adjacent radial rolling cutter located on a radially inner side thereof, such that front ends of all the radial rolling cutters in each rolling cutter set are located on the same fitting circular arc.

[0011] In some embodiments, each radial rolling cutter is mounted in a separate cutter case, and protrudes forward with respect to a front end face of the cutter case, wherein the cutters further comprise radial tearing cutters located at a radially outer edge of the cutter case and projecting forwardly relative to the cutter case.

- [0012] In some embodiments, a distance by which the radial tearing cutter protrudes with respect to the front end face of the cutter case is smaller than that by which the radial rolling cutter protrudes.
- 5 [0013] In some embodiments, a distance between a front end of the radial rolling cutter and a front end of a corresponding radial tearing cutter along the rotation axis is in a range of 15mm-20mm.
- [0014] In some embodiments, the radial tearing cutter protrudes forward parallel to the rotation axis.
- 10 [0015] In some embodiments, the cutters further comprise a scraper set which is disposed at a rear side of the radial rolling cutter set in a rotational direction of the base, and comprises a plurality of scrapers arranged in the radial direction.
- [0016] In some embodiments, both sides of the radial rolling cutter set are provided with the scraper sets.
- 15 [0017] In some embodiments, a distance by which the scraper protrudes with respect to the front end face of the cutter case is smaller than that by which the radial rolling cutter protrudes.
- [0018] In some embodiments, a distance between a front end of the radial rolling cutter and a front end of a corresponding scraper along the rotation axis is in a range of 15mm-20mm.
- 20 [0019] In some embodiments, the cutters further comprise a central cutter disposed in a central region of the base and extending in the radial direction, the central cutter being configured as a sandwich structure formed by a plurality of cutter layers which are arranged in a direction perpendicular to an extending direction of the central cutter.
- [0020] In some embodiments, the central cutter comprises two sets arranged in a crisscross pattern.
- 25 [0021] In some embodiments, a leading edge of the central cutter is formed as an inwardly concave arcuate structure.
- [0022] In some embodiments, the cutters further comprise a central rolling cutter set disposed in a central region of the base.
- 30 [0023] In some embodiments, the central rolling cutter set includes a plurality of central rolling cutters arranged in the radial direction, the central rolling cutter having a central rolling cutter rotation axis extending in the radial direction.

- [0024] In some embodiments, connection lines of front ends of the plurality of central rolling cutters are formed as an inwardly concave arc shape.
- [0025] In some embodiments, each central rolling cutter constituting the central rolling cutter set is disposed at a position offset relative to the rotation axis in the radial direction.
- 5 [0026] In some embodiments, the plurality of central rolling cutters are supported by the same rotating shaft, or the plurality of central rolling cutters are respectively supported by different rotating shafts.
- [0027] In some embodiments, the cutters further comprise a central tearing cutter disposed outside an end of the central rolling cutter set in an arrangement direction of the central rolling cutters.
- 10 [0028] In some embodiments, the central rolling cutter set is formed as a modular unitary structure, the base is provided with a central hole in the central region, and the central rolling cutter set is integrally mounted in the central hole.
- [0029] In some embodiments, cutting edges of the rolling cutters constituting the radial rolling cutter set and/or the central rolling cutter set are embedded with a hard alloy having a hardness greater than 85 HRA.
- 15 [0030] In some embodiments, an additional tearing cutter is disposed on a radially outer side of the radial rolling cutter set, the additional tearing cutter protruding forward in an outwardly oblique manner with respect to the rotation axis.
- 20 [0031] In some embodiments, the cutters comprise inclined rolling cutters disposed radially outside the radial rolling cutter set, and having an inclined rolling cutter rotation axis inclined in such a manner as to be close to the rotation axis in the excavation direction.
- [0032] In some embodiments, the cutters further comprise protection cutters disposed on a periphery side of the base and projecting relative to a periphery surface.
- 25 [0033] In some embodiments, each radial rolling cutter has an opposing radial rolling cutter set arranged at an angle of 180° relative to the rotation axis.
- [0034] In some embodiments, a minimum gap between cutting trajectories formed by different radial rolling cutters constituting the radial rolling cutter set is in a range of 60mm-75mm.
- [0035] In some embodiments, the excavation equipment has a muck convey mechanism
- 30 located behind the cutter head in the excavating direction, and the base is provided with a

grating portion which allows the muck generated during cutting to pass through, wherein the muck convey mechanism has screw blades, and a maximum passing size of the grating portion is smaller than a pitch of the screw blades.

[0036] According to another aspect of the present application, there is further provided an excavation equipment having the cutter head as described above.

[0037] The cutter head and the excavation equipment according to the present application have the following technical advantages:

[0038] 1. Since the radial rolling cutter rotation axis is arranged perpendicular to the rotation axis of the cutter head, the radial rolling cutter shaft receives a uniform force during cutting, thereby avoiding the occurrence of eccentric wear, and prolonging the service life of the rolling cutters. Particularly for the radial rolling cutters farther from the rotation axis of the cutter head, the advantageous effect is more significant.

[0039] 2. The radial rolling cutters at different positions are interchangeable, which improves the maintenance efficiency and reduces the maintenance cost.

[0040] 3. The radial rolling cutters are arranged in a stepwise descending manner from the center to the periphery. In this manner, front ends of the plurality of radial rolling cutters in the same radial rolling cutter set may form a circular arc profile fitting curve, which can be well adapted to the arc-shaped structure of the main channel segment and is adapted to cutting operation on the main tunnel segment during construction of cross passage using mechanical method.

BRIEF DESCRIPTION OF THE DRAWINGS

[0041] For the sake of better understanding on the above and other objectives, features, advantages, and functions of the present disclosure, the preferred embodiments are provided with reference to the drawings. The same reference symbols refer to the same components throughout the drawings. It would be appreciated by those skilled in the art that the drawings are merely provided to illustrate preferred embodiments of the present disclosure, without suggesting any limitation to the protection scope of the present disclosure.

[0042] FIG. 1 is a perspective view of a preferred embodiment of a cutter head according to the present application;

[0043] FIG. 2 is a side view of the cutter head shown in FIG. 1;

[0044] FIG. 3 is a front view of the cutter head shown in FIG. 1;

[0045] FIG. 4 is a schematic view of a sandwich structure of central cutters of the cutter head shown in FIG. 1;

[0046] FIG. 5 is a schematic view in which the cutter head shown in FIG. 1 fits with a segment;

5 [0047] FIG. 6 is a perspective view of another preferred embodiment of a cutter head according to the present application;

[0048] FIG. 7 is a side view of the cutter head shown in FIG. 6;

[0049] FIG. 8 is a front view of the cutter head shown in FIG. 6;

[0050] FIG. 9 is a perspective view of a base of the cutter head shown in FIG. 6;

10 [0051] FIG. 10 and FIG. 11 show a central rolling cutter set of the cutter head shown in FIG. 6; and

[0052] FIG. 12 is a schematic view in which the cutter head shown in FIG. 1 fits with a segment.

DETAILED DESCRIPTION OF EMBODIMENTS

15 [0053] Reference now will be made to the drawings to describe embodiments of the present disclosure. What will be described herein are only preferred embodiments according to the present disclosure. On the basis of the preferred embodiments, those skilled in the art can implement other embodiments of the present disclosure which all fall within the scope of the present disclosure.

20 [0054] In order to realize network intercommunication between underground space, a large number of T-shaped connection tunnels need to be constructed, such, section cross passages of subways and highway, subway accesses and air shafts, inspection wells of municipal pipe tunnel, air shafts in long tunnel middle, connecting line of water-related affairs tunnel, etc. A mechanical method for the construction of a T-shaped cross passage of a tunnel system is
25 recently proposed. For this construction method, the present application provides a cutter head of an excavation equipment capable of carrying out mechanical excavation on an original main tunnel, without need of dismantling the segment of the main tunnel and having good adaptability to the space curved surface of the segment. One example of the excavation equipment may be a shield machine.

[0055] As shown in FIG. 1, a cutter head 1 according to a preferred embodiment of the present application has a base 10 that is substantially configured as a circular shape. In a state of being mounted to the excavation equipment, the base 10 can be driven by the excavation equipment to rotate about a mounting shaft. The mounting shaft defines a rotation axis AX1 of the base 10 (see FIG. 2). Cutters 20 are mounted on the base 10. Upon performing the cutting operation, the cutter head 1 contacts with a working surface (e.g., a cross-section/heading face of the cross passage) by means of the cutters 20, presses the working surface under the action of a jacking force received by the excavation equipment, and breaks the working surface using the cutters 20 to achieve the cutting and excavation. The cutters 20 substantially comprise rolling cutters 21, tearing cutters 22, scrapers 23, central cutters 24 and periphery protection cutters 25. Detailed depictions will be presented below with reference to the figures.

[0056] The rolling cutters 21 are mounted on the base 10 and can rotate about its own rotation axis AX2. The rotation axis AX2 of each rolling cutter extends substantially along a radial direction of the base 10 (the radial direction is defined by the rotational axis AX1), i.e., being perpendicular to a rotational direction of the base 10. During cutting and excavation, the excavation equipment is applied with a jacking force in an excavation direction F, so that the rolling cutter 21 is pressed against the working surface. As the base 10 rotates about the rotation axis AX1, the cutting cutter 21, driven by the base 10, rotates about its own rotation axis AX2 and walks on the working surface to form a cutting trajectory. In this way, the edge of the rolling cutter 21 is pressed into the working surface, breaks the rock or soil strata and achieves cutting and excavation.

[0057] In order to perform simultaneous cutting on the entire work surface, the cutter head 1 is provided with a plurality of rolling cutter sets. Each rolling cutter set comprises a plurality of rolling cutters 21 arranged substantially in the radial direction of the base 10. The rolling cutter set may also be referred to as a radial rolling cutter set. Accordingly, the rolling cutters 21 constituting the radial rolling cutter set may also be referred to as radial rolling cutters. Preferably, the plurality of rolling cutter sets are arranged along a circumferential direction of the base 10 (the circumferential direction is defined by the rotation axis AX1) at uniform interval. Preferably, each rolling cutter set has an opposing rolling cutter set arranged at 180° with respect to the rotation axis AX1, in order to avoid a screw conveyor which conveys broken stone from jam caused by rolling failure of the rolling cutters (due to a too large pitch between the rolling cutter sets), and to ensure a uniform bearing stress on the rolling cutter sets which can low the damage rate of the cutters and achieve a better cutting performance. Depending on the

arrangement manners of the rolling cutters, the number of rolling cutters in the two opposing rolling cutter sets may be the same or different. For example, in some embodiments, the cutter head 1 may comprise four (radial) rolling cutter sets arranged in a substantially “cross” shape. In some embodiments, the cutter head 1 may comprise eight (radial) of rolling cutter sets arranged in a substantially “eight-pointed star” shape.

[0058] To achieve cutting on the entire working surface, in one arrangement manner, the rolling cutters 21 are arranged in a generally helical trajectory on the base 10. For example, the cutter head 1 is provided with N rolling cutter sets, one set of which may be predetermined as a starting rolling cutter set. For each rolling cutter set, the rolling cutter 21 closest to the rotation axis AX1 may be referred to as a first-order rolling cutter, which is followed radially outward by a second-order rolling cutter, a third-order rolling cutter, ..., and a M-order rolling cutter. It will be appreciated that the number M of rolling cutters in different rolling cutter sets may be the same or different. In a clockwise direction (or a counterclockwise direction), starting from the next rolling cutter set adjacent to the starting rolling cutter set, a radial distance of the rolling cutter of each order in a downstream rolling cutter set from the rotation axis AX1, is greater than the radial distance of the same-order rolling cutter in an adjacent upstream rolling cutter set from the rotation axis AX1, up to the Nth rolling cutter set. Furthermore, the radial distance of the M+1th-order rolling cutter in the starting rolling cutter set from the rotation axis AX1 is greater than the radial distance of the Mth-order rolling cutter in an adjacent upstream rolling cutter set from the rotation axis AX1. As such, connection lines formed by sequentially connecting the same-order rolling cutter in different rolling cutter sets in the clockwise direction (or counter-clockwise direction) starting from the first-order rolling cutter in the starting rolling cutter set and connecting the M+1th-order rolling cutter in the starting rolling cutter set with the M-order rolling cutter in an adjacent upper rolling cutter set, are substantially configured as a trajectory of a helical line. The rolling cutters may be formed in a single helical line arrangement or a double helical line arrangement depending on a size of an area of the working surface, a degree of hardness of the rock strata which affects a wear rate of the rolling cutters, the number of needed rolling cutters, etc.

[0059] In another arrangement, the same-order rolling cutter in different rolling cutter sets may be set at an equal radial distance from the rotation axis AX1, i.e., when connecting the same-order rolling cutters in different rolling cutter sets, the connection lines of different-order rolling cutters are substantially formed as a substantially concentric circular trajectory. The number of rolling cutters in different rolling cutter sets may be the same or different.

[0060] It may be appreciated that cutting trajectories formed by different rolling cutters 21 on the working surface (heading face) are a plurality of concentric circles, as the cutter head 1 rotates about the rotational axis AX1. Preferably, the rolling cutter sets are arranged such that a minimum gap between the cutting trajectories formed by different rolling cutters is in a range of 60mm-75mm. That is, in the cutting trajectories formed by the rolling cutter sets, a gap between adjacent trajectories is set in a range of 60mm-75mm. In this way, it is possible to avoid failure of rock breaking due to insufficient fissures caused by too large gap between adjacent trajectories. Thus, the cutter head 1 can be adapted for cutting hard rock formations.

[0061] According to the present application, in each rolling cutter set, the rolling cutter rotation axis AX2 (which may also be referred to as radial rolling cutter rotation axis) of each rolling cutter 21 is arranged perpendicular to the rotation axis AX1 of the base 10. It may be appreciated that the jacking force F applied on the excavation equipment determines its excavation direction along which the rotation axis AX1 is defined. Therefore, the direction of the jacking force F is also the direction of the rotation axis AX1. Similarly, a pressing force applied on the rolling cutters 21 between the excavation equipment and the working surface is in the direction of the rotation axis AX1. Since the rolling cutter rotation axis AX2 is arranged perpendicular to the rotation axis AX1, a pressure received by a rolling cutter shaft (which defines the rolling cutter rotation axis AX2) of the rolling cutter 21 is substantially perpendicular to its length direction, with very few force components in other directions. Such an arrangement may enable the rolling cutters 21 to receive a uniform force in the cutting process, avoid the occurrence of eccentric wear, facilitate prolonging the service life of the rolling cutters 21. Particularly for the rolling cutters 21 farther from the rotation axis AX1, the advantageous effect is more significant.

[0062] Furthermore, in order to better fit the segments of the main tunnel at the starting of excavation, the rolling cutter 21 is arranged in the following way: in each rolling cutter set, each rolling cutter 21 is arranged to be backward by a predetermined distance in the excavation direction relative to an adjacent rolling cutter 21 located on a radially inner side thereof, so that front ends of all the rolling cutters 21 in the rolling cutter set can be located on the same fitting circular arc (see FIG. 5 and FIG. 12). For example, as shown in FIG. 2, the rolling cutter 21b is arranged to be backward by a predetermined distance as compared with an adjacent rolling cutter 21a on the radially inner side thereof, and the rolling cutter 21c is arranged to be backward by another predetermined distance as compared with the adjacent rolling cutter 21b on the radially inner side thereof. Preferably, the farther the rolling cutter 21 is from the rotation axis

AX1 in the radial direction, the greater the distance it is backward with respect to the adjacent rolling cutter 21 on the radially inner side thereof, so that the shape of the circular arc can be better fitted.

[0063] Such an arrangement forms a stepwise descending manner of the rolling cutters 21 from the center to the circumference while ensuring that the rolling cutter rotation axis AX2 of the rolling cutter 21 is perpendicular to the rotation axis AX1 of the base 10. In this way, front ends of the plurality of rolling cutters 21 in the rolling cutter set may form a circular arc profile fitting curve, which enables the plurality of rolling cutters 21 to simultaneously contact the main tunnel segment 100, and ensures simultaneous cutting at different positions. In addition, such an arrangement improves the interchangeability of the rolling cutters 21 at different positions, in particular different radial positions. Since all the rolling cutters 21 are arranged in the same manner that the rolling cutter rotation axis AX2 is perpendicular to the rotation axis AX1 of the base 10, and it is not necessary to consider an inclination angle of the rolling cutter shaft with respect to the rotation axis AX1 of the base 10, the rolling cutters 21 at different positions may have the same specification. When one of the rolling cutters 21 is damaged, it may be quickly replaced with any spare rolling cutter 21.

[0064] During actual production, each of the rolling cutters 21 is mounted in a separate cutter case 211 by a rolling cutter shaft, and protrudes outward with respect to a front end face of the case 211. The cutter cases 211 are fixed to predetermined positions of the base 10 to form a rolling cutter set. It may be appreciated that the more fitting points there are, the closer the distance between the points becomes, the smoother a resultant fitting curve is, the higher the fitting degree is. Therefore, in order to fit the curvature of the segment with the above arrangement of the rolling cutters 21, it is necessary to arrange as many rolling cutters 21 as possible in the radial direction, and the distance between adjacent rolling cutters 21 is very compact. In this case, adjacent cutter cases 211 are arranged side by side in the radial direction, and it is difficult to have a space to arrange other parts. However, since the cutter case 211 located on a radially outer side is arranged to be backward as compared with the cutter case 111 located on a radially inner side, a radially outer front end of the cutter case 211 located on the radially inner side is exposed to the external. In the process of cutting the arc surface, the outer front end of the cutter case 211 is prone to contact with the working surface, which causes wear, and even the cutter case 211 is damaged, which causes the failure of the rolling cutter 21. It may be appreciated that this problem is caused by cutting the arc surface and does not occur when a planar surface is cut.

[0065] Preferably, as shown in FIG. 1 and FIG. 2, a tearing cutter 22 is disposed at a position of a radially outer edge of the cutter case 211. The tearing cutter 22 protrudes forward with respect to the front end face of the cutter case 211, that is, the highest point of the tearing cutter 22 is higher than the front end face of the cutter case 211. In this manner, the tearing cutter 22 comes into contact with the working surface earlier than the outer front end of the cutter case 211, and can cut and destroy the working surface, thereby preventing the wear caused by the contact of the cutter case 211 with the working surface and providing good protection. Preferably, the tearing cutter 22 projects forward in a manner parallel to the rotation axis AX1 (i.e., substantially perpendicular to the front end face of the cutter case 211). Further preferably, a distance by which the tearing cutter 22 protrudes forward is smaller than that by which the rolling cutter 21 protrudes forward, so that the rolling cutter 21 comes into contact with the working surface earlier than the tearing cutter 22 located on the radially outer side thereof. Preferably, the front end of the rolling cutter 21 goes beyond the front end of the tearing cutter 22 located at the radially outer side thereof by a distance in a range of 15mm-20mm in the excavation direction, i.e., the direction of the rotation axis AX1.

[0066] Referring to FIG. 1, an additional tearing cutter 22a is disposed on a radially outer side of part of the rolling cutter sets. Unlike the tearing cutter 22 disposed at the outer edge of the cutter case 211, the additional tearing cutter 22a extends obliquely outward at an angle with respect to the rotation axis AX1.

[0067] In addition, on both sides in the radial direction of the cutter case 211 of the rolling cutter 21, scrapers 23 are also provided protruding forward with respect to the front end face of the cutter case 211. A plurality of scrapers 23 are arranged in a radial direction to form a scraper set. After the rolling cutter 21 breaks a rock stratum or soil stratum on the working surface as the base 10 rotates, the scrapers 23 may scrape loose rock blocks or soil blocks to expose a new working surface to be cut for subsequent cutting work. Thus, in practice, only the scrapers 23 located behind the rolling cutter 21 in the rotation direction of the base 10 work. Preferably, a distance by which the scraper 23 protrudes forward with respect to the front end face of the cutter case 211 is smaller than that by which the rolling cutter 21 protrudes forward. Preferably, in the excavation direction, i.e., in the direction of the rotation axis AX1, the front end of the rolling cutter 21 goes beyond the front end of the scraper 23 at a corresponding position by a distance in a range of 15mm-20mm. Preferably, a scraper set is disposed on both radial sides of the rolling cutter set. In this way, when the cutter head 1 operates to rotate in two rotation directions, i.e., a clockwise rotation direction and a counterclockwise rotation

direction, respectively, on a rear side of the rolling cutter set, there is always a corresponding scraper set acting to scrape loose rock blocks or soil blocks.

[0068] Referring to FIG. 1 through FIG. 3, on a radially inner side of the plurality of rolling cutter sets, the base 10 is formed with a central region 11 in which a central cutter 24 is disposed.

5 The central cutter 24 is formed in a strip-like structure extending in a substantially radial direction. In the illustrated embodiment, there are provided with two sets of central cutters 24 which are arranged in a crisscross pattern. Preferably, as shown in FIG. 4, the central cutter 24 is constructed as a sandwich structure, for example, it may be formed by sandwiching cutter layers (e.g., different alloy cutter lades) of different strength and toughness to increase wear

10 resistance and service life while improving its cutting ability. Further preferably, an arrangement direction of the cutter layers is perpendicular to an extension direction of the central cutter 24. In other words, as the central cutters 24 contact with the working surface, when the base 10 rotates, a force generated by the working surface on the central cutters 24 follows a rotation direction R of the central cutters 24, i.e., coincides with the arrangement

15 direction of the cutter layers. Therefore, the arrangement direction of the cutter layers may effectively resist a forces exerted by the working surface against the central cutters 24 and reduce the damage rate thereof.

[0069] Preferably, with reference to FIG. 1, a leading edge of the central cutter 24 is configured as an inwardly concave arcuate structure. As compared to a structure in which a

20 leading edge projects forwardly, the leading edge of the central cutter 24 is concave inwardly so that the central cutter 24 can make initial contact with the working surface at two positions at both ends of the concave arcuate structure, so that the central cutter 24 better “grasps” the working surface, i.e., being positioned relative to the working surface, thereby avoiding the central cutter 24 from shifting over the working surface. This is particularly advantageous

25 when the central cutter 24 initially cuts a main tunnel segment at receiving end which protrudes convexly toward the excavation equipment.

[0070] As shown in FIG. 1 through FIG. 3, there are protection cutters 25 provided on a periphery side of the base 10. Specifically, a plurality of protection cutters 25 are provided at interval in the circumferential direction and protrude outward with respect to the periphery

30 surface. In this way, when the cutter head 1 rotates, the protection cutters 25 contact the soil stratum or rock stratum on the periphery side earlier than the base 10, thereby avoiding wear of the base 10 due to directly contact and friction against the soil stratum or rock stratum.

[0071] FIG. 6 through FIG. 12 show a cutter head 2 according to another preferred embodiment of the present application. The arrangement manners of most mechanisms in the cutter head 2 are substantially the same as or similar to those of corresponding mechanisms in the cutter head 1 shown in FIG. 1 through FIG. 5. Mechanisms having similar structures or functions are given the same reference numerals.

[0072] As shown in FIG. 6 and FIG. 8, the cutter head 2 is provided with a set of rolling cutters 26 in the central region 11, instead of the strip-shaped extending central cutters. In order to distinguish from the rolling cutter set constituted by the rolling cutters 21, the rolling cutters 26 may be referred to as central rolling cutters, and the rolling cutter set constituted by them may be referred to as a central rolling cutter set 29. Accordingly, the rolling cutters 21 may be referred to as radial rolling cutters, and the rolling cutter sets constituted by them may be referred to as radial rolling cutter sets.

[0073] As compared to the cutter head 1, the cutter head 2 is more suitable for performing cutting operations on hard rock formations. In the cutter head 2, the cutting operation is performed on the working surface at a central position via the central rolling cutters. As compared with the strip-shaped central cutters 24 having the sandwich structure in the cutter head 1, the central rolling cutters 26 are in rolling friction contact with the working surface, whereas the strip-shaped central cutters 24 are in sliding friction contact with the working surface. Therefore, the cutter head 2 can reduce the wear caused by the collisional friction between the cutters in the central region and the hard rock formation. Further, the central rolling cutters 26 press the hard rock formation by a cutting edge at the edge thereof under the jacking force, and can produce a better rock-breaking effect than the strip-shaped central cutters 24.

[0074] Further referring to FIG. 8, in some embodiments, a central rolling cutter set 29 comprises a plurality of center rolling cutters 26 arranged in a radial direction of the base 10, and meanwhile the central rolling cutters 26 have a central rolling cutter rotation axis AX3 extending in the radial direction. In this way, as the cutter head 2 rotates about the rotation axis AX1, the central rolling cutters 26 rotate about their own central rolling cutter rotation axes AX3 in a manner similar to that of the radial rolling cutters 21, and meanwhile press against and walk on the working surface to generate a cutting trajectory. In order to ensure normal operation of the central rolling cutters 26, preferably all the central rolling cutters 26 are disposed at positions radially offset from the rotational axis AX1. That is, the central rolling

cutters 26 are prevented from being disposed exactly at the position of the rotation axis AX1 in order to avoid that the central rolling cutters 26 cannot rotate about their own central rolling cutter rotation axes AX3.

5 [0075] In some embodiments, the central rolling cutter set 29 may be provided as a modular unitary structure. For example, referring to FIG. 9 through FIG. 11, a plurality of central rolling cutters 26 may be provided in the same rolling cutter case 291, so that the plurality of center rolling cutters 26 may be integrally mounted and detached through the rolling cutter case 291. Preferably, in order to facilitate the mounting and detaching operations, the base 10 is further provided with a central hole 12 for receiving the rolling cutter case 291 at the position
10 of the central region 11. Preferably, in the modular central rolling cutter set 29, the plurality of central rolling cutters 26 may be supported by the same rotating shaft, but each central rolling cutter 26 may freely rotate with respect to other central rolling cutters 26. Alternatively, the plurality of central rolling cutters 26 may be provided to be respectively supported by different rotating shafts.

15 [0076] Preferably, referring to FIG. 11, the cutting edge of the central rolling cutter 26 may be embedded with a hard alloy 261, such as carburized alloy steel, tungsten carbide, or the like. Hardness of the hard alloy 261 is usually greater than 85 HRA, e.g., 85-90 HRA. In this way, the hardness and wear resistance of the central rolling cutter 26 can be increased, thereby enabling a better rock breaking capacity, especially for hard rock formations. Similarly, radial
20 rolling cutters 21 or rolling cutters disposed at other positions may also employ the same arrangement.

[0077] Further referring to FIG. 11, similar to the central cutters 24 in the cutter head 1, in some embodiments, the central rolling cutter set 29 is arranged such that connection lines of front ends of the plurality of central rolling cutters 26 are formed in an inwardly concave arcuate
25 shape. In this manner, when the central rolling cutter set 29 contacts with the formation or segment to be cut, it makes initial contact with the formation or segment at two positions at both ends of the concave arcuate structure, so that the central rolling cutter set 29 better “grasps” the working surface, i.e., is positioned relative to the working surface, thereby avoiding the central rolling cutter set 29 from shifting over the working surface. This is particularly
30 advantageous when the central rolling cutter set 24 initially cuts a main tunnel segment which is located at receiving end of the cross passage and protrudes convexly toward the excavation equipment.

[0078] In order to achieve the above-described structure, preferably, a plurality of central rolling cutters 26 are disposed to rotate around the same central rolling cutter rotation axis AX3 but have different diameters, wherein the closer one central rolling cutter 26 is to the rotation axis AX1, the smaller the diameter of the central rolling cutter 26. As the central rolling cutters 26 are positioned gradually away from the rotational axis AX1, their diameters become larger and larger. In a further embodiment, the central rolling cutters 26 may also be set to have the same diameter, but to rotate about different central rolling cutter rotation axes AX3. The central rolling cutter rotation axis AX3 of a central rolling cutter 26 close to the rotation axis AX1 is located behind the central rolling cutter rotation axis AX3 of a central rolling cutter 26 far away from the rotation axis AX1 in the excavation direction.

[0079] Preferably, as shown in FIG. 6 and FIG. 8, central tearing cutters 27 are disposed outside the ends of the central rolling cutter set 29 in the arrangement direction of the central rolling cutters 26 and protrude forward in the excavation direction from the end face of the rolling cutter case 291. In operation, the central tearing cutters 27 come into contact with the working surface earlier than the rolling cutter case 291, to cut and break the working surface. In this way, it is possible to prevent the rolling cutter case 291 of the central rolling cutter set 29 from being damaged due to contact and friction with the working surface. It may be understood that the tearing cutters 22 arranged radially outside the radial rolling cutters 21 may be referred to as radial tearing cutters, in order to distinguish from the central tearing cutters 27.

[0080] Further referring to FIG. 6 and FIG. 8, unlike the cutter head 1, the cutter head 2 omits additional tearing cutters radially outward of the radial rolling cutter set, and instead provides inclined rolling cutters 28. The inclined rolling cutters 28 are arranged in substantially the same way as the radial rolling cutters 21, with a difference lying in that a inclined rolling cutter rotation axis AX4 of the inclined rolling cutters 28 is inclined with respect to the rotation axis AX1 of the cutter head 2, i.e., close to the rotation axis AX1 along the excavation direction. Accordingly, the orientation of the cutting edge of the inclined rolling cutter 28 is inclined relative to the rotation axis AX1 (i.e., forward in the excavation direction) in a manner of both forward and radially outwardly. In this way, the inclined rolling cutters 28 can complement the circular arc profile fitting curve formed by the radial rolling cutter sets so that the cutter head 2 conforms more closely to the circular arc shape of the main tunnel segment or the like.

[0081] In addition, as shown in FIG. 9, in the cutter head 2, a grating portion 13 is further provided at a position of the base 10 where the cutters are not provided. The debris or muck

such as soil generated by the cutters cutting the working surface may be conveyed to the rear of the cutter head 2 through the grating portion 13, and conveyed by a muck convey mechanism of the excavation equipment or in other manners from a working position of the cutting and excavation to other areas such as a predetermined storage area. In some embodiments, the muck convey mechanism may be a screw conveyor that provides a driving force with screw blades. Preferably, the grating portion 13 is configured such that its maximum passing dimension is less than a pitch of the screw blades. In this way, the grating portion 13 may block broken stones or the like having a size exceeding the pitch outside the cutter head without entering the screw conveyor to prevent obstruction of the screw conveyor.

10 **[0082]** In addition, according to another aspect of the present application, there is also provided an excavation equipment which may have the cutter head as described above. The excavation equipment may be specifically, for example, a shield machine.

[0083] The above description of the various embodiments of the application is provided to one of ordinary skill in the relevant art for purposes of this description. It is not intended that the application excludes other embodiments or is limited to a single disclosed embodiment. As above, many alternatives and modifications of the present disclosure will be apparent to those of ordinary skill in the art. Thus, while some alternative embodiments have been described in detail, other embodiments will be apparent or relatively readily developed by those of ordinary skill in the art. This application is intended to cover all alternatives, modifications and variations of the present disclosure described herein, as well as other embodiments falling within the spirit and scope of the present disclosure described above.

I/We Claim:

1. A cutter head for an excavation equipment, wherein the cutter head comprises:
a base (10) rotatable about a rotation (AX1) axis in an excavation direction of the excavation equipment; and

5 cutters mounted on the base (10), the cutters comprising a plurality of radial rolling cutter sets spaced-apart in a circumferential direction defined relative to the rotation axis (AX1), each of the radial rolling cutter sets comprising a plurality of radial rolling cutters (21) arranged radially starting from the rotation axis (AX1) in a radial direction defined relative to the rotation axis (AX1);

10 wherein, in each radial rolling cutter set, each radial rolling cutter (21) is rotatable about a radial rolling cutter rotation axis (AX2) perpendicular to the rotation axis (AX1), and each radial rolling cutter (21) is arranged to be backward by a predetermined distance in the excavation direction relative to an adjacent radial rolling cutter (21) located on a radially inner side thereof, such that front ends of all the radial rolling cutters (21) in each rolling cutter set
15 are located on a same fitting circular arc.

2. The cutter head according to claim 1, wherein each radial rolling cutter (21) is mounted in a separate cutter case (211), and protrudes forward with respect to a front end face of the cutter case (211),

20 wherein the cutters further comprise radial tearing cutters (22) located at a radially outer edge of the cutter case (211) and projecting forwardly relative to the cutter case (211).

3. The cutter head according to claim 2, wherein a distance by which the radial tearing cutter (22) protrudes with respect to the front end face of the cutter case is smaller than that by
25 which the radial rolling cutter (21) protrudes.

4. The cutter head according to claim 3, wherein a distance between a front end of the radial rolling cutter (21) and a front end of a corresponding radial tearing cutter (22) along the rotation axis (AX1) is in a range of 15mm-20mm.

30 5. The cutter head according to claim 2, wherein the radial tearing cutter (22) protrudes forward parallel to the rotation axis (AX1).

6. The cutter head according to claim 1, wherein the cutters further comprise a scraper set which is disposed at a rear side of the radial rolling cutter set in a rotational direction of the base (10), and comprises a plurality of scrapers (23) arranged in the radial direction.
- 5 7. The cutter head according to claim 6, wherein both sides of the radial rolling cutter set are provided with the scraper sets.
8. The cutter head according to claim 6, wherein a distance by which the scraper (23) protrudes with respect to the front end face of the cutter case is smaller than that by which the radial rolling cutter (21) protrudes.
- 10 9. The cutter head according to claim 8, wherein distance between a front end of the radial rolling cutter (21) and a front end of a corresponding scraper (23) along the rotation axis (AX1) is in a range of 15mm-20mm.
- 15 10. The cutter head according to claim 1, wherein the cutters further comprise a central cutter (24) disposed in a central region (11) of the base (10) and extending in the radial direction, the central cutter (24) being configured as a sandwich structure formed by a plurality of cutter layers which are arranged in a direction perpendicular to an extending direction of the central cutter.
- 20 11. The cutter head according to claim 10, wherein the central cutter (21) comprises two sets arranged in a crisscross pattern.
- 25 12. The cutter head according to claim 10, wherein a leading edge of the central cutter (24) is formed as an inwardly concave arcuate structure.
13. The cutter head according to claim 1, wherein the cutters further comprise a central rolling cutter set (29) disposed in a central region (11) of the base (10).
- 30 14. The cutter head according to claim 13, wherein the central rolling cutter set (29) includes a plurality of central rolling cutters (26) arranged in the radial direction, the central rolling cutter (26) having a central rolling cutter rotation axis (AX3) extending in the radial

direction.

15. The cutter head according to claim 14, wherein connection lines of front ends of the plurality of central rolling cutters (26) are formed as an inwardly concave arc shape.

5

16. The cutter head according to claim 14, wherein each central rolling cutter (26) constituting the central rolling cutter set (29) is disposed at a position offset relative to the rotation axis (AX1) in the radial direction.

10

17. The cutter head according to claim 14, wherein the plurality of central rolling cutters (26) are supported by the same rotating shaft, or the plurality of central rolling cutters (26) are respectively supported by different rotating shafts.

15

18. The cutter head according to claim 14, wherein the cutters further comprise a central tearing cutter (27) disposed outside an end of the central rolling cutter set (29) in an arrangement direction of the central rolling cutters (26).

20

19. The cutter head according to claim 13, wherein the central rolling cutter set (29) is formed as a modular unitary structure, the base (10) is provided with a central hole (12) in the central region (11), and the central rolling cutter set (29) is integrally mounted in the central hole (12).

25

20. The cutter head according to claim 13, wherein cutting edges of the rolling cutters constituting the radial rolling cutter set and/or the central rolling cutter set are embedded with a hard alloy having a hardness greater than 85 HRA.

30

21. The cutter head according to claim 1, wherein an additional tearing cutter (22a) is disposed on a radially outer side of the radial rolling cutter set, the additional tearing cutter (22a) protruding forward in an outwardly oblique manner with respect to the rotation axis (AX1).

22. The cutter head according to claim 1, wherein inclined rolling cutters (28) are disposed radially outside the radial rolling cutter set, the inclined rolling cutters (28) having an inclined rolling cutter rotation axis (AX4) inclined in such a manner as to be close to the rotation

axis (AX1) in the excavation direction.

23. The cutter head according to claim 1, wherein the cutters further comprise protection cutters (25) disposed on a periphery side of the base (10) and projecting relative to a periphery surface.

24. The cutter head according to claim 1, wherein each radial rolling cutter has an opposing radial rolling cutter set arranged at an angle of 180° relative to the rotation axis (AX1).

25. The cutter head according to claim 1, wherein a minimum gap between cutting trajectories formed by different radial rolling cutters (21) constituting the radial rolling cutter set is in a range of 60mm-75mm.

26. The cutter head according to claim 1, wherein the excavation equipment has a muck convey mechanism located behind the cutter head in the excavating direction, and the base is provided with a grating portion (13) which allows muck generated during cutting to pass through, wherein the muck convey mechanism has screw blades, and a maximum passing size of the grating portion (13) is smaller than a pitch of the screw blades.

27. An excavation equipment, wherein the excavation equipment has the cutter head according to any of claims 1-26.