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(54) **Title:** SYSTEM AND METHOD, BASED ON ROCK AND MINERAL ANALYSIS, FOR TUNNEL FAULT FRACTURE ZONE FORECASTING FOR TBM

(54) 发明名称: 基于岩石矿物分析的TBM隧道断层破碎带预报系统及方法

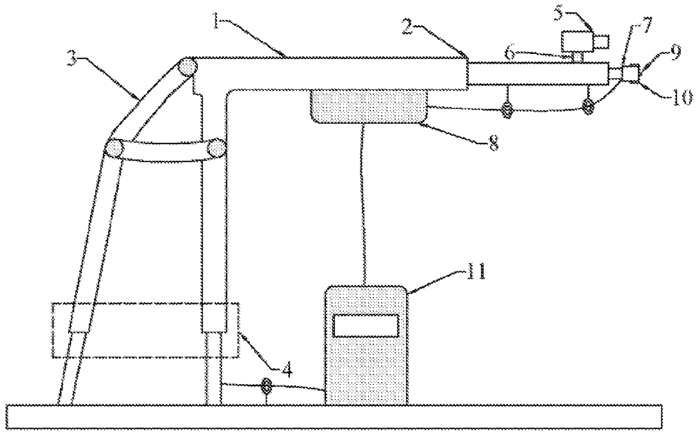

图 1

(57) **Abstract:** A system and method, based on rock and mineral analysis, for tunnel fault fracture zone forecasting for a TBM. The system comprises a mechanical arm apparatus (1) and a data analysis module (11) mounted on the TBM. The mechanical arm apparatus (1) comprises a mechanical arm main body that can stretch and retract horizontally and ascend and descend vertically, and has a certain degree of freedom in pitch angle. A laser Raman spectrometer detector (7) is arranged in the axial direction of the front end of the mechanical arm main body. Laser ranging modules (10) are distributed on the circumference of the laser Raman spectrometer detector (7) to measure the distance between the laser Raman spectrometer detector (7) and surrounding rocks, so as to ensure that the detector is in vertical contact with the surrounding rocks at all times. A rock image collection apparatus (5) is arranged on the front end of the mechanical arm main body. The data analysis module (11) is configured to receive testing results of the rock image collection apparatus (5), the laser ranging modules (10) and the laser Raman spectrometer detector (7), and obtain, according to the data of multiple measuring points, surrounding rock images and mineral compositions and the change rules of content along with the mileage of a tunnel face, thereby forecasting a fault fracture zone ahead of the tunnel face.

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本国际公布:
– 包括国际检索报告(条约第21条(3))。

(57) 摘要: 一种基于岩石矿物分析的TBM隧道断层破碎带预报系统及方法，系统包括搭载于TBM上的机械臂装置（1）和数据分析模块（11），机械臂装置（1）包括能够水平伸缩、竖直升降以及具有一定俯仰角自由度的机械臂主体，机械臂主体的前端轴向设置有激光拉曼光谱仪探测器（7），激光拉曼光谱仪探测器（7）的圆周分布有激光测距模块（10），以探测激光拉曼光谱仪探测器（7）与围岩之间的距离，保证探测器与围岩始终垂直接触；机械臂主体的前端上设置有岩石图像采集装置（5）；数据分析模块（11）被配置为接收岩石图像采集装置（5）、激光测距模块（10）和激光拉曼光谱仪探测器（7）的检测结果，根据多个测点的数据，得到围岩图像、矿物成分和含量随掌子面里程的变化规律，进而对隧道掌子面前方断层破碎带进行预报。

FORECASTING SYSTEM AND METHOD FOR FAULT FRACTURE ZONE OF TBM TUNNEL BASED ON ROCK MINERAL ANALYSIS

Field of the Invention

The present disclosure belongs to the field of tunnel TBM (Tunnel Boring Machine)-mounted fault fracture zone forecasting, and specifically relates to a forecasting system and method for a fault fracture zone of a TBM tunnel based on rock mineral analysis.

Background of the Invention

The statement of this section merely provides background art information related to the present disclosure and does not necessarily constitute the prior art.

When TBM tunnel construction encounters a fault fracture zone, it is very likely to induce serious geological disasters such as jamming, water inrush, and collapse under construction disturbance. Therefore, the occurrence of the fault fracture zone needs to be forecasted accurately during the TBM tunnel construction.

As the inventors know, different types of fault fracture zone bodies have different disaster-causing mechanisms and modes. For example, the central zone of a compressive fault bears huge pressure, rock fractures are ground relatively thinly and mostly filled and cemented by mylonite and fault gouge to prevent water, while dense fracture zones on two walls of the fault have good connectivity and strong water conductivity, and water inrush disasters are prone to occur during tunnel construction for exposing this section; and an extensional fault has large gaps in its central zone and relatively poor water permeability on two walls, which is conducive to the enrichment of groundwater, and when a fault fracture zone is exposed by tunnel excavation, the groundwater often carries sand, gravel, etc. into the tunnel. Therefore, it is particularly important to timely and accurate forecast the type of a fault fracture zone body.

The existing advanced geological forecasting methods for TBM tunnels are mainly geophysical detection methods, such as seismic wave methods and induced polarization methods. These methods can forecast the location and scale of a fault fracture zone relatively accurately, but cannot forecast the type of the fault fracture zone.

Summary of the Invention

To solve the above problems, the present disclosure proposes a forecasting system and method for a fault fracture zone of a TBM tunnel based on rock mineral analysis, which can timely obtain a rock mineral composition and content near a tunnel face, and forecast a fault fracture zone in the front tunnel face based on the changes in the mineral composition and content.

According to some embodiments, the present disclosure adopts the following technical solutions:

A forecasting system for a fault fracture zone of a TBM tunnel based on rock mineral analysis, including a mechanical arm device and a data analysis module mounted on a TBM, wherein:

the mechanical arm device includes a mechanical arm body capable of extending and retracting horizontally and lifting vertically and having a certain degree-of-freedom of a pitching angle, a laser Raman spectrometer detector is axially arranged at a front end of the mechanical arm body, and laser ranging modules are distributed on the periphery of the laser Raman spectrometer detector, to detect the distance between the laser Raman spectrometer detector and the surrounding rock, to ensure that the detector is always in vertical contact with the surrounding rock; a rock image capture device is arranged above the front end of the mechanical arm body;

the data analysis module is configured to receive the detection results of the rock image capture device, the laser ranging modules, and the laser Raman spectrometer detector, obtain the change rule of the surrounding rock image, the mineral composition and content with the mileage of a tunnel face, and then forecast a fault fracture zone for the front tunnel face.

As an optional embodiment, the mechanical arm body includes at least two sleeved mechanical arm sections to form a horizontally extending and retracting mechanism, a vertically lifting mechanism is arranged at a lower end of the mechanical arm body and is capable of driving the mechanical arm to move up and down, and the relative angle of the mechanical arm body and the vertically lifting mechanism is adjustable. This can ensure that the mechanical arm body can swing up and down at a certain angle, thereby ensuring that the laser Raman spectrometer detector can be in close contact with the tunnel surrounding rock.

As an optional embodiment, a pressure sensor is arranged at a front end of the laser Raman spectrometer detector, to test the pressure between the tunnel surrounding rock and the laser Raman spectrometer detector, so as to prevent the detector from being damaged due to excessive contact pressure.

As an optional embodiment, the rock image capture device is a miniature camera and is equipped with a flashlight function.

As an optional embodiment, a rotatable base is arranged on an upper side of the front end of the mechanical arm body, and the rock image capture device is arranged on the rotatable base to implement omnidirectional image capture on the vault and the surrounding rock around.

As an optional embodiment, the data analysis module is remotely and wirelessly connected to a main control unit of a TBM main control room.

As an optional embodiment, the mechanical arm body is a multi-degree-of-freedom mechanical arm.

A working method based on the above-mentioned system includes: capturing an image of a tunnel surrounding rock behind a TBM shield to determine a mineral composition test part, the mechanical arm device driving the laser Raman spectrometer to move to a corresponding position to test the mineral composition and content of the tunnel surrounding rock, determining the change rule of the mineral composition and content of the tunnel surrounding rock with the mileage of a tunnel face according to the rock image captured by the rock image capture device at a plurality of measuring points, and finally forecasting a fault fracture zone for the front tunnel face according to the rock image and the change rule of the mineral composition and content.

As an optional embodiment, at least 5 measuring points are adopted, and then an average value of various measuring points is calculated as a mineral content value of the test part.

As an optional embodiment, the test interval of a lithological unchanging area is not more than 10 m.

Compared with the prior art, the beneficial effects of the present disclosure are:

The present disclosure can conveniently, quickly and timely measure the mineral composition and content of the surrounding rock in a TBM tunnel, avoids inconvenient testing in traditional rock testing methods implemented in laboratories, saves manpower, material resources, and financial resources;

The present disclosure can test the mineral composition and content of the tunnel surrounding rock for a long time, provide their change rule with the mileage of the tunnel face, and implement advanced geological forecasting in time without TBM shutdown.

Brief Description of the Drawings

The accompanying drawings constituting a part of the present disclosure are used for providing a further understanding of the present disclosure, and the schematic embodiments of the present disclosure and the descriptions thereof are used for interpreting the present disclosure, rather than constituting improper limitations to the present disclosure.

Fig. 1 is a schematic diagram of an overall structure in this embodiment;

Fig. 2 is a schematic diagram of a front end structure of a detector in this embodiment;

Fig. 3 is a simplified flowchart of operation steps in this embodiment;

Fig. 4 is a schematic diagram of a mineral analysis test part in a lithological unchanging area in this embodiment; and

Fig. 5 is a schematic diagram of a mineral analysis test part of a lithological contact zone in this embodiment.

Detailed Description of Embodiments

The present disclosure will be further illustrated below in conjunction with the accompanying drawings and embodiments.

It should be noted that the following detailed descriptions are exemplary and are intended to provide further descriptions of the present disclosure. All technical and scientific terms used herein have the same meaning as commonly understood by those of ordinary skill in the technical field to which the present disclosure belongs unless otherwise indicated.

It should be noted that the terms used here are merely used for describing specific embodiments, but are not intended to limit the exemplary embodiments of the present invention. As used herein, unless otherwise clearly stated in the context, the singular form is also intended to include the plural form. In addition, it should also be understood that when the terms “include” and/or “comprise” are used in the Description, they indicate features, steps, operations, devices, components, and/or combinations thereof.

In the present disclosure, the terms such as “upper”, “lower”, “left”, “right”, “front”, “rear”, “vertical”, “horizontal”, “side”, and “bottom” indicate the orientation or positional relationships based on the orientation or positional relationships shown in the drawings, are only relationship terms determined for the convenience of describing the structural relationships of various components or elements of the present disclosure, but do not specify any component or element in the present disclosure, and cannot be understood as limitations to the present disclosure.

In the present disclosure, the terms such as “fixed”, “connected” and “coupled” should be generally understood, for example, they may be fixedly connected, detachably connected, integrally connected, directly connected, or indirectly connected by a medium. For a related scientific research or technical person in this art, the specific meanings of the above terms in the present disclosure may be determined according to specific circumstances, and cannot be understood as limitations to the present disclosure.

As shown in Fig. 1, a TBM-mounted forecasting system for a fault fracture zone in a tunnel based on rock mineral analysis includes a mechanical arm device, a rock mineral analysis device, a rock image capture device, laser ranging devices, and a data control analysis device.

The mechanical arm device 1 is composed of a horizontal extension and retraction module 2, an up-and-down swing module 3, and a vertically lifting module 4; the horizontal extension and retraction module 2 and the vertically lifting module 4 are composed of telescopic rods for horizontal extension and retraction and vertically lifting of the mechanical arm device.

The up-and-down swing module 3 is located between the horizontal extension and retraction module 2 and the vertically lifting module 4, composed of a triangular hinge structure, and used for enabling a mechanical arm body to swing up and down at a certain angle, to ensure that a laser Raman spectrometer detector 7 can be in close contact with tunnel surrounding rock.

The rock image capture device 5 is mounted above the horizontal extension and retraction module 2 of the mechanical arm, is used to capture an image of the surrounding rock in the tunnel and is an existing miniature camera, and test results are transmitted to a data processing and analysis device 11; the miniature camera is equipped with a flashlight function, and the flashlight is in a working state when the image of the surrounding rock is acquired; the base of the miniature camera is a rotating device 6, which is used for the miniature camera to implement omnidirectional image capture on the vault and the surrounding rock around.

The laser Raman spectrometer detector 7 of the rock mineral analysis device is located in front of the horizontal extension and retraction module 2 of the mechanical arm, and the body 8 is located below the horizontal extension and retraction module 2 of the mechanical arm.
As shown in Fig. 2, a micro pressure sensor 9 is arranged at a front end of the laser Raman spectrometer detector 7, to test the pressure between the tunnel surrounding rock and the laser Raman spectrometer detector 7, to prevent the detector from being damaged due to excessive contact pressure.
As shown in Fig. 2, the laser ranging devices 10 are distributed on the periphery of the laser Raman spectrometer detector 7, to detect the distance between the Raman spectrometer detector 7 and the surrounding rock, to ensure that the detector is always in vertical contact with the surrounding rock.
The data control analysis device 11 receives data of rock mineral analysis and surrounding rock image capture and is used to control the operations of various devices such as the mechanical arm 1, the rock image capture device 5, the laser ranging devices 10, and the rock mineral analysis device 8.
As shown in Fig. 3, a forecasting method for a fault fracture zone based on the above-mentioned mineral analysis system includes the following steps:
the rock image capture device 5 captures an image of tunnel surrounding rock behind a TBM shield to determine a mineral composition test part;
the vertically lifting module 4 and the horizontal extension and retraction module 2 of the mechanical arm are moved to corresponding positions, and the laser Raman spectrometer detector 7 tests the mineral composition and content of the tunnel surrounding rock. As shown in Fig. 4, preferably, at least 5 measuring points are adopted, respectively are Op1, Op2, Op3, Op4, and Op5. Then an average value of the 5 measuring points is calculated as a mineral content value of the test part;
the TBM continues to bore forward, and the above test steps are repeated for the next test part to test the mineral composition and content of the rock. Preferably, as shown in Fig. 4, the test interval of a lithological unchanging area should not be more than 5 m. As shown in Fig. 5, a lithological contact zone is divided into 3 mineral test areas A, B, and C according to the rock image captured by the rock image capture device for testing. The measuring points in area A are A1 to A5, the

measuring points in area B are B1 to B5, the measuring points in area C are C1 to C5, and an average value of the 5 measuring points in each area is calculated respectively as a mineral content value of the test part;

the data control analysis device 11 obtains the change rule of the surrounding rock image, the mineral composition and content with the mileage of a tunnel face, and finally forecasts a fault fracture zone for the front tunnel face according to the change rule of the surrounding rock image, the mineral composition and content.

In the above step, the forecasting method of a fault fracture zone for the front tunnel face according to the change rule of the surrounding rock image, the mineral composition and content is as follows:

if approaching the tunnel face, the content of minerals such as chlorite, sericite, kaolinite, and montmorillonite in the tunnel surrounding rock increases, and the filling quaternary sediments appear in surrounding rock fractures, then an extensional fracture zone may be in the front tunnel;

if approaching the tunnel face, the content of flaky, needle-like, and fibrous minerals such as illite, saponite, muscovite, chlorite, epidote, serpentine, and montmorillonite in the tunnel surrounding rock increases, and the fracture degree of the surrounding rock gradually increases to argillization, then a compressive fracture zone may be in the front tunnel.

Described above are merely preferred embodiments of the present disclosure, and the present disclosure is not limited thereto. Various modifications and variations may be made to the present disclosure for those skilled in the art. Any modification, equivalent substitution, improvement, or the like made within the spirit and principle of the present disclosure shall fall into the protection scope of the present disclosure.

Although the specific embodiments of the present disclosure are described above in combination with the accompanying drawing, the protection scope of the present disclosure is not limited thereto. It should be understood by those skilled in the art that various modifications or variations could be made by those skilled in the art based on the technical solution of the present disclosure without any creative effort, and these modifications or variations shall fall into the protection scope of the present disclosure.

2020409772 09 Oct 2023

CLAIMS

1. A forecasting system for a fault fracture zone of a TBM tunnel based on rock mineral analysis, comprising a mechanical arm device and a data analysis module mounted on a TBM, wherein:

the mechanical arm device comprises a mechanical arm body capable of extending and retracting horizontally and lifting vertically and having a certain degree-of-freedom of a pitching angle, a laser Raman spectrometer detector is axially arranged at a front end of the mechanical arm body, and laser ranging modules are distributed on the periphery of the laser Raman spectrometer detector, to detect the distance between the laser Raman spectrometer detector and the surrounding rock, to ensure that the detector is always in contact with the surrounding rock; a rock image capture device is arranged above the front end of the mechanical arm body; and

the data analysis module is configured to receive the detection results of the rock image capture device, the laser ranging modules, and the laser Raman spectrometer detector, obtain the change rule of the surrounding rock image, the mineral composition and content with the mileage of a tunnel face, and then forecast a fault fracture zone for the front tunnel face;

wherein the mechanical arm body comprises at least two sleeved mechanical arm sections to form a horizontally extending and retracting mechanism, a vertically lifting mechanism is arranged at a lower end of the mechanical arm body and is capable of driving the mechanical arm to move up and down, and the relative angle of the mechanical arm body and the vertically lifting mechanism is adjustable;

the laser Raman spectrometer, being driven by the mechanical arm device, moves to a corresponding position to test the mineral composition and content of the tunnel surrounding rock.

2. The forecasting system for a fault fracture zone of a TBM tunnel based on rock mineral analysis according to claim 1, wherein a pressure sensor is arranged at a front end of the laser Raman spectrometer detector to test the pressure between the tunnel surrounding rock and the laser Raman spectrometer detector.

3. The forecasting system for a fault fracture zone of a TBM tunnel based on rock mineral analysis according to claim 1, wherein the rock image capture device is a miniature camera and is equipped

with a flashlight function.

4. The forecasting system for a fault fracture zone of a TBM tunnel based on rock mineral analysis according to claim 1, wherein a rotatable base is arranged on an upper side of the front end of the mechanical arm body, and the rock image capture device is arranged on the rotatable base to implement omnidirectional image capture on the vault and the surrounding rock around.

5. The forecasting system for a fault fracture zone of a TBM tunnel based on rock mineral analysis according to claim 1, wherein the data analysis module is remotely and wirelessly connected to a main control unit of a TBM main control room.

6. The forecasting system for a fault fracture zone of a TBM tunnel based on rock mineral analysis according to claim 1, wherein the mechanical arm body is a multi-degree-of-freedom mechanical arm.

7. A working method based on the forecasting system according to any one of claims 1-6, comprising: capturing an image of a tunnel surrounding rock behind a TBM shield to determine a mineral composition test part, the mechanical arm device driving the laser Raman spectrometer to move to a corresponding position to test the mineral composition and content of the tunnel surrounding rock, determining the change rule of the mineral composition and content of the tunnel surrounding rock with the mileage of a tunnel face according to the rock image captured by the rock image capture device at a plurality of measuring points, and finally forecasting a fault fracture zone for the front tunnel face according to the rock image and the change rule of the mineral composition and content.

8. The working method according to claim 7, wherein at least 5 measuring points are adopted, and then an average value of various measuring points is calculated as a mineral content value of the test part.

9. The working method according to claim 7, wherein the test interval of a lithological unchanging

area is not more than 10 m.

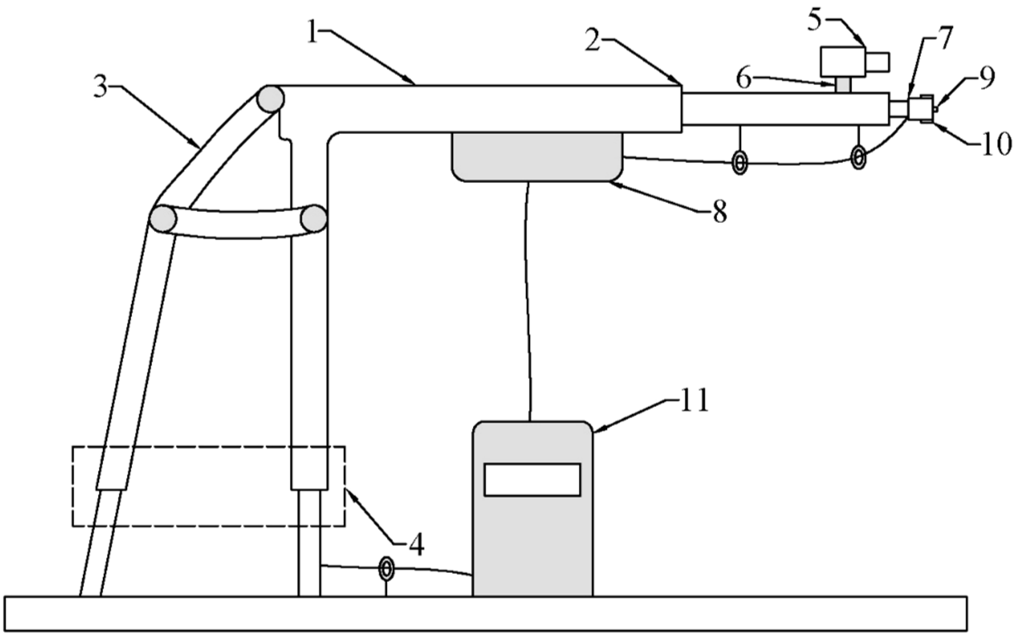

Fig. 1

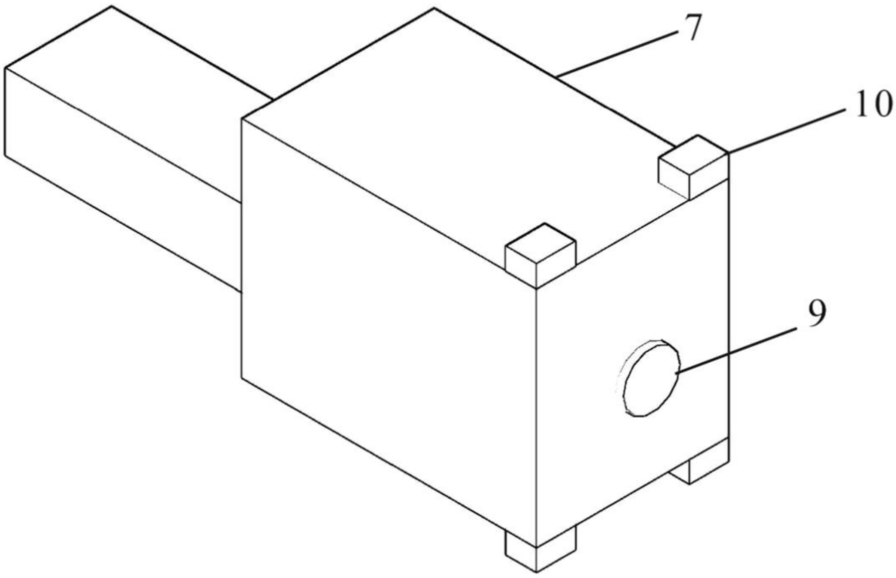

Fig. 2

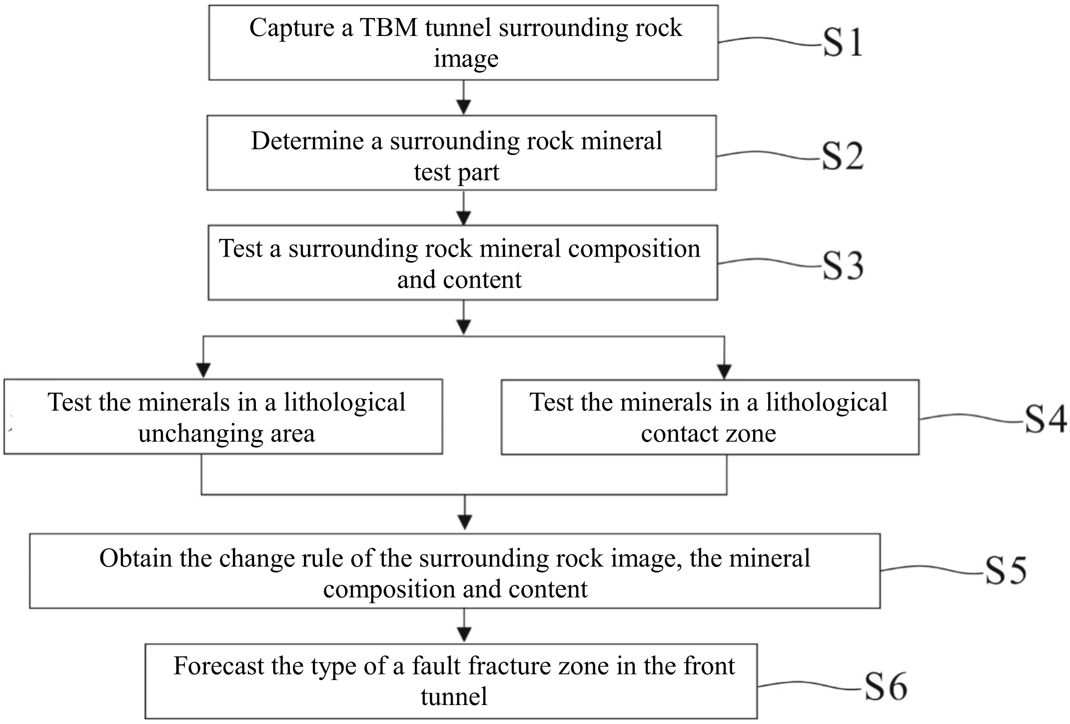
Capture a TBM tunnel surrounding rock image
S1
Determine a surrounding rock mineral test part
S2
Test a surrounding rock mineral composition and content
S3
Test the minerals in a lithological unchanging area
Test the minerals in a lithological contact zone
S4
Obtain the change rule of the surrounding rock image, the mineral composition and content
S5
Forecast the type of a fault fracture zone in the front tunnel
S6

Fig. 3

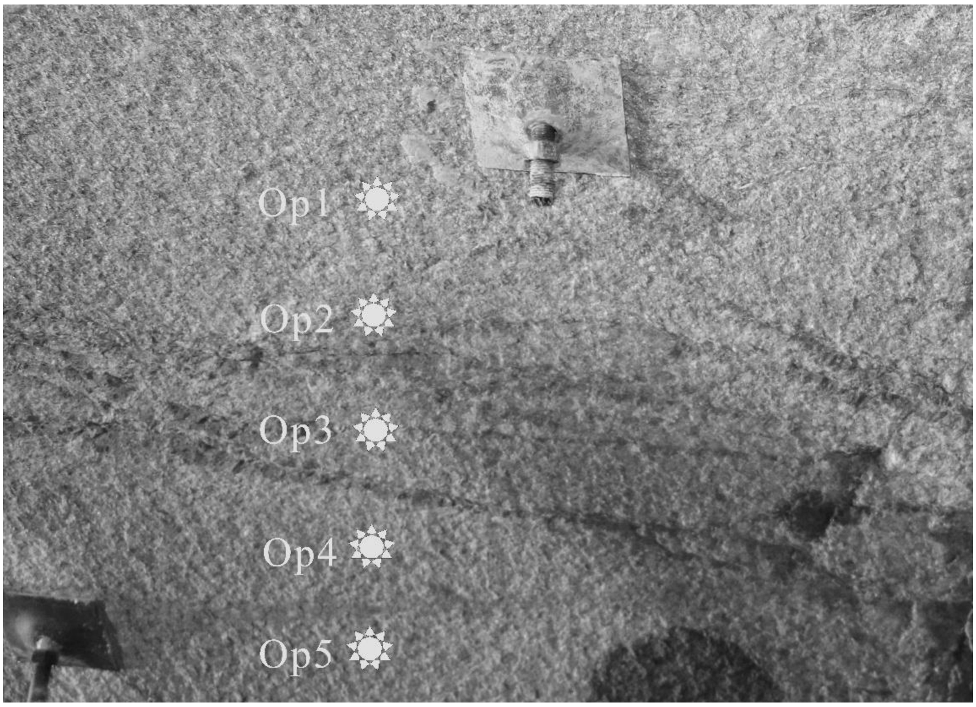
Op1
Op2
Op3
Op4
Op5

Fig. 4

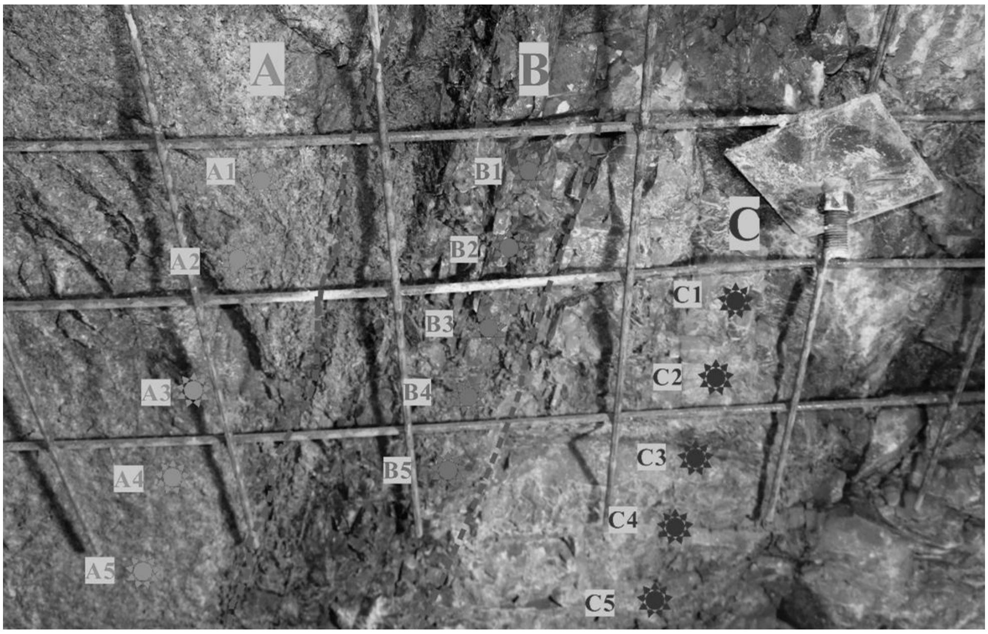

Fig. 5