JACKING SYSTEM FOR EXCAVATION CONSTRUCTION OF CROSS PASSAGE AND CONSTRUCTION METHOD USING THE SAME

FIELD

[0001]

[0002] The present disclosure relates to the technical field of underground engineering, and particularly to a jacking system for excavation construction of a cross passage and a construction method using the same.

BACKGROUND

[0003] 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. 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 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 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.

[0004] In recent years, the use of modular cross passage structure combined with mechanical excavation of cross passage has been proposed. In a starting stage, a preliminary support trolley is unfolded and supported on a segment of a main tunnel in all directions, up, down, left and right, to form a full-ring integral preliminary support structure, and a reaction frame is supported on a segment of the main tunnel at a side opposite to an excavation direction and serves as a back support of the jacking device to bear jacking force. Taking subway tunnel construction as an example, an inner diameter of the tunnel usually ranges from 5.5m to 6m,

and even up to 8.1m or larger in some projects. For the tunnel construction of other projects, its inner diameter may be larger or smaller. Conventional preliminary support structure can only meet requirement of tunnel having inner diameter varying from 5.5m and 7.1mm. When the tunnel inner diameter is larger than 7.1m, for example increased to 8.1m, the system of the preliminary support structure will be very massive if the same support method is employed. Furthermore, as the tunnel's inner diameter becomes larger, re-study on the respective adaptability and stability of the support structure and the segment structure of the main tunnel, as well as the variation of stresses and structural strength during the construction process, is necessary. The conventional construction method cannot provide any reference.

[0005] In addition, the whole space of the main tunnel where the full-ring integral preliminary support structure is employed is occupied by the support structure, such that vehicles cannot pass by, and both sides of the construction site cannot communicate with each other. As a result, the construction of other cross passages or the other side of the main tunnel can only be carried out after the construction of one cross passage is completed. It is impossible for multiple construction processes to be carried out simultaneously, which causes a prolonged construction schedule. On the other hand, the angle adjustment of the planned advance line can only be realized by on site manual operation on the main components in the prior art, such as the rear support and jacking system.

[0006] Accordingly, it is necessary to provide a jacking system for excavation construction of a cross passage and a construction method using the jacking system to at least partially solve the above problems while controlling equipment-manufacturing costs and construction costs.

SUMMARY

[0007] An object of the present disclosure is to provide a jacking system for excavation construction of a T-shaped cross passage of a tunnel system and a construction method using the jacking system, to implement simultaneous construction of multiple processes, improve the construction efficiency, shorten a construction period, and reduce the apparatus-manufacturing costs and construction costs.

[0008] A jacking system for excavation construction of a T-shaped cross passage of a tunnel system according to an aspect of the present disclosure comprises a reaction frame and force transmission member, the cross passage is used to communicate with at least one main channel, the force transmission member connects the reaction frame to a main tunnel segment located at

a side of the reaction frame facing the cross passage and surrounding a starting end of the cross passage, the reaction frame is used to provide support for an excavation apparatus in an excavation direction, wherein a supporting force is transmitted to the main tunnel segment surrounding the starting end of the cross passage via the force transmission member in a way that the force transmission member bears a pulling force.

[0009] In some embodiments, the force transmission member comprises a plurality of force transmission pull rods arranged spaced-apart around a circumferential direction of the cross passage.

[0010] In some embodiments, at least part of the transfer transmission pull rods are directly connected to the main tunnel segment surrounding the starting end of the cross passage.

[0011] In some embodiments, the starting end of the cross passage is provided with a starting casing connected to the main tunnel segment, at least part of the force transmission pull rods being connected to the starting casing.

[0012] In some embodiments, the force transmission pull rod is configured as an unpowered pull rod.

[0013] In some embodiments, the force transmission pull rod is configured as a powered pull rod capable of providing a driving force.

[0014] In some embodiments, the powered pull rod is a reverse pulling force hydraulic cylinder.

[0015] In some embodiments, each of the powered pull rods has an independent control unit.

[0016] In some embodiments, the jacking system further comprises a slide rail extending along a central axis of the cross passage, the reaction frame being movable along the slide rail.

[0017] In some embodiments, one end of the force transmission pull rod is pivotally connected to the reaction frame, and/or the other end of the force transmission pull rod is pivotally connected to the main tunnel segment or to a starting casing connected to the main tunnel segment. Preferably, the pivot axis of the force transmission pull rod is perpendicular to the axial direction of the cross passage.

[0018] In some embodiments, one end of the force transmission pull rod is removably connected to the reaction frame, and/or the other end of the force transmission pull rod is removably connected to the main tunnel segment or a starting casing connected to the main

tunnel segment.

[0019] In some embodiments, the force transmission pull rod is removably disposed by a coupling device, the coupling device comprising:

a mounting base having two side walls which are opposite and spaced apart, an end of said force transmission pull rod being disposed between the two side walls; and

a pin, wherein the mounting base and an end of the force transmission pull rod are respectively provided with a mounting hole, and the pin passes through the mounting holes of the mounting base and the force transmission pull rod.

[0020] In some embodiments, the mounting base is fixedly disposed on the reaction frame, or the mounting base is fixed on the main tunnel segment, or the jacking system comprises a starting casing fixedly connected to the main tunnel segment, the mounting base is fixed on the starting casing.

[0021] In some embodiments, an end of the force transmission pull rod is provided with a fine adjustment structure, the mounting hole passes through the fine adjustment structure, and the fine adjustment structure has a drum-shaped outwardly-projecting circumferential surface surrounding the mounting hole.

[0022] In some embodiments, the force transmission member is configured as a barrel-shaped structure disposed around the starting end of the cross passage.

[0023] In some embodiments, the barrel-shaped structure is directly connected to the main tunnel segment surrounding the starting end of the cross passage.

[0024] In some embodiments, the starting end of the cross passage is provided with a starting casing connected to the main tunnel segment, the barrel-shaped structure being connected to the starting casing.

[0025] In some embodiments, an axial end of the barrel-shaped structure is provided with a radially outwardly extending flange by which the barrel-shaped structure is connected and secured.

[0026] In some embodiments, a connection manner of the barrel-shaped structure comprises welding, bolting and/or riveting.

[0027] In some embodiments, a sidewall of the barrel-shaped structure is provided with reinforcing ribs.

[0028] In some embodiments, a sidewall of the barrel-shaped structure is provided with a material delivery hole therethrough.

[0029] In some embodiments, the barrel-shaped structure is an integrally formed structure or is assembled from at least two separate parts.

[0030] In some embodiments, when the barrel-shaped structure is assembled from at least two separate parts, the at least two separate parts are identical to each other.

[0031] In some embodiments, a side of the reaction frame facing the cross passage is provided with a jacking drive unit including a plurality of hydraulic cylinders in a quadrant-symmetrical manner and spaced-apart around a central axis of the cross passage.

[0032] In some embodiments, one end of the plurality of hydraulic cylinders is connected to the reaction frame and the other end is connected to an annular abutment member which is used to abut against the excavation apparatus or the segment of the cross passage.

[0033] In some embodiments, the hydraulic cylinders are mounted on the reaction frame and at least partially disposed in an interior of the reaction frame.

[0034] In some embodiments, a corollary equipment of the jacking drive unit is disposed in the interior of the reaction frame, and the corollary equipment at least comprises a hydraulic control device, an oil pipe, an oil tank and/or a valve.

[0035] In some embodiments, the hydraulic cylinder comprises a cylinder barrel and a piston, a front end of the cylinder barrel being provided with a flange and the cylinder barrel abutting against the reaction frame via the flange in a direction opposite to the excavation direction.

[0036] In some embodiments, the flange is connected to the reaction frame by fasteners.

[0037] In some embodiments, a surface of the reaction frame is provided with a boss that abuts against the flange.

[0038] In some embodiments, the hydraulic cylinder comprises a cylinder barrel and a piston, a bottom of the cylinder barrel abutting against the reaction frame.

[0039] In some embodiments, the jacking system further comprises a trolley provided at the starting end, and the reaction frame is supported by the trolley, wherein the reaction frame is provided with an adjustment unit for adjusting a relative position between the reaction frame and the trolley.

[0040] In some embodiments, the adjustment unit comprises adjustment drive cylinders

disposed along three mutually orthogonal adjustment directions, and one of the adjustment directions is an excavation direction.

[0041] In some embodiments, the reaction frame is provided with lug portions on left and right sides of the excavation direction, and at least part of the adjustment drive cylinders are disposed on the lug portions.

[0042] In some embodiments, the adjustment unit comprises a first adjustment drive cylinder and a second adjustment drive cylinder at least in the excavation direction, and an adjustment stroke of the second adjustment drive cylinder is greater than that of the first adjustment drive cylinder.

[0043] In some embodiments, the second adjustment drive cylinder is disposed at the bottom of the reaction frame.

[0044] In some embodiments, a side of the reaction frame away from the cross passage is provided with a travel space running through in an extension direction of the main tunnel.

[0045] In some embodiments, a travel platform is laid in the travel space.

[0046] In some embodiments, the travel platform is provided with a travel track extending in the extension direction of the main tunnel.

[0047] In some embodiments, the jacking system further comprises a working platform disposed on the main tunnel segment below the jacking system, the reaction frame and/or the travel platform being supported on the working platform.

[0048] In some embodiments, the jacking system further comprises additional force transmission member connecting the reaction frame to the main tunnel segment at a side of the reaction frame away from the cross passage, a force of the excavation apparatus acting on the reaction frame is transmitted to the main tunnel segment via the force transmission member and the additional force transmission member, and the travel space extends through the additional force transmission member.

[0049] In some embodiments, the additional force transmission member comprises a plurality of support rods arranged about an axis of the cross passage, the plurality of support rods including an upper support rod portion and a lower support rod portion, and the travel space being disposed between the upper support rod portion and the lower support rod portion.

[0050] In some embodiments, the jacking system further comprises a bearing base having a

surface shaped close to the main tunnel segment, and the support rod is coupled to the bearing base and supported on the main tunnel segment by the bearing base.

[0051] In some embodiments, the support rod comprises at least two sub-sections disposed in a lengthwise direction, and adjacent sub-sections are detachably connected and fixed to each other by a connector.

[0052] In some embodiments, a material delivery hole running through the reaction frame is disposed at a position of the reaction frame corresponding to the cross passage.

[0053] A method of using a jacking system for excavation construction of a T-shaped cross passage of a tunnel system according to an aspect of the present disclosure comprises:

delivering a jacking system, an excavation apparatus and a corollary equipment to a position where a cross passage is to be excavated, and fixing them;

adjusting positions of the jacking system and the excavation apparatus according to a planned excavation direction;

connecting a reaction frame to a main tunnel segment through a force transmission member;

moving the excavation apparatus to a planned starting position;

excavating and assembling cross passage modular units;

completing the construction of the cross passage.

[0054] In some embodiments, before the step of delivering a jacking system, an excavation apparatus and a corollary equipment to a position where a cross passage is to be excavated, the method further comprises:

combining the corollary equipment, the jacking system and the excavation apparatus into a unitary structure.

[0055] In some embodiments, the corollary equipment comprises a starting casing, and the method further comprises:

connecting the starting casing with the main tunnel segment, and connecting the reaction frame to the starting casing via a force transmission member.

[0056] In some embodiments, the excavation apparatus is a shield tunneling machine, and the method further comprises, prior to the step of excavating and assembling cross passage modular

units:

mounting a pre-starting auxiliary segment and a steel structure.

[0057] In some embodiments, the excavation apparatus is a pipe jacking tunneling machine, the force transmission member is an unpowered force transmission pull rod, the cross passage modular unit is a pipe section, and the method further comprises, prior to the step of excavating and assembling cross passage modular units:

mounting a jacking drive unit which acts directly on the reaction frame.

[0058] In some embodiments, the step of excavating and assembling cross passage modular units comprises:

using the pipe jacking machine to complete spatial advancement of the pipe section;

disconnecting and removing at least part of the force transmission pull rods that interfere with a pipe section delivery passage, from the section delivery passage;

retracting the jacking drive unit;

delivering the pipe section to an assembling position to complete assembling;

extending the jacking drive unit out to complete close contact with the assembled pipe section;

restoring the force transmission pull rod to a connected state.

[0059] In some embodiments, the excavation apparatus is the pipe jacking tunneling machine, the force transmission member is a force transmission pull rod capable of providing a driving force, the cross passage modular unit is a pipe section, and the step of excavating and assembling cross passage modular units comprises:

disconnecting and removing the force transmission pull rods that interfere with a pipe section delivery passage, from the pipe section delivery passage;

delivering the pipe section to an assembling position to complete assembling;

restoring the force transmission pull rod to a connected state;

driving the force transmission pull rod to push the pipe jacking method tunneling machine forward via the reaction frame to complete the excavation of the pipe section;

driving the force transmission pull rod reversely to retract the reaction frame.

[0060] In some embodiments, before the step of driving the force transmission pull rod reversely to retract the reaction frame, the method comprises:

fixing a section closest to the reaction frame by a retaining device.

[0061] A jacking system for excavation construction of a T-shaped cross passage of a tunnel system according to an aspect of the present disclosure comprises a reaction frame and a plurality of force transmission pull rods, the cross passage is used to communicate with a main channel at least at a receiving end in an excavation direction, an end of the force transmission pull rod is connected to the reaction frame, the other end of the transmission pull rod passes through a soil layer and is connected to a main tunnel segment surrounding the receiving end of the cross passage, the reaction frame is used to provide support for an excavation apparatus in an excavation direction, wherein a supporting force is transmitted to the main tunnel segment surrounding the receiving end of the cross passage via the force transmission pull rods.

[0062] In some embodiments, an inner surface of the main tunnel segment surrounding the receiving end of the cross passage is provided with a bearing base, and the force transmission pull rods pass through the main tunnel segment and are connected to the bearing base.

[0063] In some embodiments, the bearing base is a structure that is separate from the main tunnel segment and has sides shaped close to an inner surface of the main tunnel segment.

[0064] In some embodiments, the bearing base is a steel structure.

[0065] In some embodiments, the bearing base is a prefabricated reinforced concrete structure integrally disposed with the main tunnel segment.

[0066] In some embodiments, an end of the force transmission pull rod passes through the bearing base and is locked with fasteners.

[0067] In some embodiments, the end of the force transmission pull rod is provided with a slot perpendicular to an axial direction thereof, and the fastener is configured as a clip fixed on the bearing base, and the clip is snap-fitted with the slot.

[0068] In some embodiments, the end of the force transmission pull rod is provided with a threaded structure, and the fastener is configured as a locking nut that threadably engages the threaded structure.

[0069] In some embodiments, a washer is disposed between the locking nut and the bearing base.

[0070] In some embodiments, the end of the force transmission pull rod is provided with a through hole extending therethrough in a direction perpendicular to its own axial direction, and the fastener is configured as a locking pin extending through the through hole.

[0071] In some embodiments, a plurality of the force transmission pull rods are connected to the same bearing base.

[0072] In some embodiments, each pull rod comprises a plurality of sub-sections arranged in an axial direction thereof, with adjacent sub-sections being connected and secured by a connector.

[0073] In some embodiments, a structural strength of the connector is not lower than that of the sub-sections.

[0074] In some embodiments, the force transmission pull rod comprises a hollow tube and a force transmission cable passing through the hollow tube, wherein the hollow tube is disposed in the soil layer, and the force transmission cable is configured to connect with the reaction frame and the main tunnel segment surrounding the receiving end of the cross passage.

[0075] In some embodiments, the force transmission pull rod is made of threaded steel.

[0076] In some embodiments, a sealing structure for waterproofing is provided at a position of the main tunnel segment where the force transmission pull rod passes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0077] 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.

[0078] FIG. 1 is a perspective view of a jacking system according to a first preferred embodiment of the present disclosure.

[0079] FIG. 2 is a side view of the jacking system shown in FIG. 1.

[0080] FIG. 3 is a perspective view of a jacking system according to another preferred embodiment of the present disclosure.

[0081] FIG. 4 is a perspective view of a reaction frame of the jacking system shown in FIG. 3.

[0082] FIG. 5 is a schematic view showing a prepared state of the jacking system according to the present disclosure before beginning to excavate.

[0083] FIG. 6 through FIG. 9 are schematic views of different states of the jacking system during tunneling according to the present disclosure.

[0084] FIG. 10 is a force analysis model on a segment of a main tunnel and a tunnel portal ring of the cross passage.

[0085] FIG. 11 and FIG. 12 are force analysis results of the segment of the main tunnel and the tunnel portal ring under different jacking pressure, respectively.

[0086] FIG. 13 is a schematic view of a cross section of the main tunnel upon construction of the cross passage by a mechanical method using the jacking system according to the present disclosure.

[0087] FIG. 14 shows a fine adjustment structure of a force transmission pull rod.

[0088] FIG. 15 is a perspective view of a jacking system according to a second preferred embodiment of the present disclosure.

[0089] FIG. 16 is a side view of the jacking system shown in FIG. 15.

[0090] FIG. 17 is a perspective view of a force transmission member of the jacking system shown in FIG. 15.

[0091] FIG. 18 is a perspective view of a jacking system according to a third preferred embodiment of the present disclosure.

[0092] FIG. 19 is a perspective view of a drive cylinder used in the reaction frame of the jacking system shown in FIG. 18.

[0093] FIG. 20 is a partial view of the reaction frame of the jacking system shown in FIG. 18.

[0094] FIG. 21 is a perspective view of the jacking system of FIG. 18 as viewed from another angle, showing the segment of the main tunnel segment and a trolley.

[0095] FIG. 22 is a perspective view of a jacking system according to a fourth preferred embodiment of the present disclosure.

[0096] FIG. 23 is a side view of the jacking system shown in FIG. 22.

[0097] FIG. 24 is a side view of the jacking system of FIG. 22, showing of a force transmission pull rod in another configuration.

[0098] FIG. 25 through FIG. 27 respectively show schematic views showing ends of the force transmission pull rods of the jacking system shown in FIG. 22, which are locked by means of different fasteners.

[0099] FIG. 28 is a side view of a jacking system according to a fifth preferred embodiment of the present disclosure.

[00100] FIG. 29 shows an improved solution of the jacking system shown in FIG. 28.

DETAILED DESCRIPTION OF EMBODIMENTS

[00101] 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.

[00102] 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. The present disclosure provides a jacking system suitable for the construction of a T-shaped cross passage of a tunnel system using mechanical method, wherein the cross passage and the main tunnel may be modular tunnels assembled by modular units such as segments or sections. The cross passages may be used to communicate one or two subway main tunnels.

[00103] As shown in FIG. 1 and FIG. 2, the jacking system 100 according to a preferred embodiment comprises a reaction frame 11 and force transmission member. Upon construction of the cross passages using the mechanical method, the jacking system 100 is fixed at a position corresponding to the cross passage to be excavated in a completed part of the main tunnel 1. The force transmission member is configured to connect the reaction frame 11 with a corresponding segment of the main tunnel 1 (which may be referred to as a main tunnel segment) surrounding a starting end of the cross passage in a way that the force transmission member transmits a pulling force therebetween. That is, the force transmission member connects the reaction frame to the main tunnel segment on a side of the reaction frame 11 facing

the cross passage. The reaction frame 11 is used to provide support for the excavation apparatus. Wherein the support force is finally transmitted through the force transmission member to the main tunnel segment surrounding the starting end of the cross passage. Thus, the force for supporting the excavation apparatus to advance is provided by the main tunnel segment on the side of the reaction frame 11 facing the cross passage.

[00104] It will be appreciated that in a conventional full-ring integral preliminary support structure, the force transmission member on the side of the reaction frame away from the cross passage is supported between the reaction frame and the main tunnel segment. The force for supporting the excavation apparatus to advance is transmitted to the main tunnel segment via the reaction frame and the force transmission member. The force transmission member has a tendency to push the main tunnel segment outward. This supporting force is ultimately carried by the soil outside the main tunnel segment. In this force model, the main tunnel segment is actually squeezed by the force transmission members and the outside soil body on both sides thereof. In the actual construction process, the squeezing force borne by the main tunnel segment is far less than a compressive strength of a material (e.g., concrete, steel, etc.) forming the main tunnel segment, such that no adverse impact will be broght to the structure of the main tunnel segment.

[00105] According to the technical solution of the present disclosure, the force for supporting the excavation apparatus to advance is finally transmitted to the main tunnel segment via the reaction frame and the force transmission member. And the force transmission member has a tendency to pull the main tunnel segment inside. In such a force model, the supporting force of the reaction frame is completely borne by the main tunnel segment. FIG. 10 through FIG. 12 show results of force analysis on the main tunnel segment and the tunnel portal ring forming the cross passage using such force model in a case where a cross passage with a diameter R2 is opened on the main tunnel segment with a diameter R1. The results show that, with the jacking system 100, a local concentrated stress of the main tunnel segment reaches up to 10MPa-20MPa, and is mainly concentrated on the periphery of the force transmission member, which can be coped with by increasing the structural strength by local reinforcement at the periphery of the force transmission member. Under the action of distributing jacking force of 250kPa~450kPa, a maximum horizontal lateral displacement of at an opening position of the cross passage reaches -1.0mm ~ -1.5mm, with a transversely inward convergence tendency, and a small impact may be exerted on other uncut full ring segments adjacent to the main tunnel segment.

[00106] Specifically, taking R1 of 8.1m and R2 of 3.65m as an example, the results of force analysis on the main tunnel segment and the tunnel portal ring forming the cross passage are shown in FIG. 11 and FIG. 12, respectively. It can be seen that when subjected to a jacking force of up to 450kPa, a maximum deformation displacement of the main tunnel segment is -1.2 mm, and a maximum deformation displacement of the tunnel portal ring forming the cross passage is -1.2 mm. Therefore, construction of the cross passage by mechanical method using the jacking system 100 according to the present disclosure can satisfy the redistribution of the stress of the main tunnel segment during a hole-breaking process of the cross passage, and ensuring the safety and stability of structure stress, thus is feasible. Even for large-diameter tunnels (e.g., with a diameter of 8.0m and above), the jacking system is still suitable.

[00107] When the cross passage is constructed by mechanical method using the jacking system 100 according to the present disclosure, the force transmission member which is located on the side of the reaction frame away from the cross passage in the conventional jacking system may be transferred to the side of the reaction frame facing the cross passage. Therefore, the supporting structure provided on the side of the main tunnel 1 away from the cross passage may be cancelled (namely, the reaction frame 11 is a no back support), so that a sufficient travel space can be provided between the side of the reaction frame away from the cross passage and the main tunnel segment (see FIG. 13). Vehicles, personnel, materials and the like may be transferred between different positions of the main tunnel 1 using the travel space located on the side of the reaction frame 11 away from the cross passage, so that a variety of construction processes can be carried out simultaneously. In particular, construction of multiple cross passages can be carried out simultaneously at different positions of the already-completed part of the main tunnel, and the supply of personnel and materials for the construction of the on-going part of the main tunnel may also be ensured, thereby advantageously greatly reducing the construction period. Preferably, the maximum distance between the side of the reaction frame away from the cross passage and the main tunnel segment on that side may be not less than one third of a radial dimension of the main tunnel, in order to ensure that the travel space is of sufficient size for travel. When the diameter of the main tunnel is large, the maximum distance of the travel space may even be not less than half the radial dimension of the main tunnel.

[00108] The jacking system according to the present disclosure may be applicable to two construction methods, namely, a tunneling shield method and a pipe jacking method. Accordingly, the excavation apparatus is respectively a shield tunneling machine (namely, a shield machine) and a pipe jacking tunneling machine. Corresponding to the shield method,

the modular unit is a segment. Corresponding to the pipe jacking method, the modular unit is a pipe section. The reaction frame 11 is made of a rigid material such as steel or a composite material in order to satisfy the function of supporting the excavation apparatus. The size of the reaction frame 11 is adapted to the size of the excavation apparatus for excavating the cross passage, and the rigidity is set so as to satisfy the requirement of resisting deformation during construction of jacking and excavation. In the figures, the reaction frame 11 is shown in a substantially rectangular shape. However, it will be appreciated that the reaction frame 11 may alternatively be configured as a circle, toroid or any other shape that meets construction requirements.

[00109] In some embodiments, the force transmission member may be configured in the form of force transmission pull rod 12. A plurality of force transmission pull rods 12 are provided to be spaced apart from one another in a circumferential direction around the cross passage, to provide a uniform force transmission effect. In the embodiment shown in FIG. 1 and FIG. 2, the force transmission pull rod 12 is an unpowered pull rod, which is only used for connection and force transmission, without providing any driving force. Preferably, the unpowered pull rod may be a steel structure pull rod, in particular a round steel, a square steel, a steel tube or a section steel, etc.

[00110] When the excavation apparatus is a pipe jacking tunneling machine, the excavation apparatus requires a driving force provided by the jacking system. Therefore, the side of the reaction frame 11 facing the cross passage is provided with a jacking drive unit 14. In some embodiments, the jacking drive unit 14 may be hydraulic cylinder. Preferably, the jacking drive unit 14 comprises a plurality of hydraulic cylinders arranged in a quadrant symmetrical manner around a central axis of the cross passage so as to provide a uniform driving force for the excavation apparatus in the circumferential direction. The angle of the advancing direction of the excavation apparatus relative to the central axis of the cross passage can be adjusted by the jacking drive unit 14 with control on the stroke of the hydraulic cylinders at different positions, in order to align the advance direction with the central axis or to meet other angle adjusting needs. Further, when the excavation apparatus is a shield tunneling machine, the excavation apparatus does not require the jacking system to provide the driving force. At this time, the jacking drive unit 14 may serve as an angle adjusting unit. As there is no need to provide a very large driving force, hydraulic cylinders of smaller sizes and specifications may be selected correspondingly. Furthermore, abutting members 141 connected to one end of the hydraulic cylinders away from the reaction frame 11 respectively may be provided. The

angle adjusting unit abuts against the excavation apparatus or the segment of the cross passage via the abutting member 141. In some embodiments, the abutting member 141 may specifically be an annular-shaped jacking member made of steel.

[00111] FIG. 3 shows an embodiment in which the force transmission pull rod 12 is a powered pull rod capable of providing the driving force. Wherein the force transmission pull rod 12 may be a reverse pulling force hydraulic cylinder, and specifically is a hydraulic jacking system which provides a reverse pull force as a main power, the length of a central rod and the reverse pull force of which can meet the requirements of driving a pipe jacking machine to advance. That is, the force transmission pull rod 12 is configured to provide a driving force by pulling the reaction frame 11 to move in order to push the excavation apparatus. In this way, it is unnecessary to provide a power device at a back side of the reaction frame 11 for pushing it forward. Preferably, each force transmission pull rod 12 has an independent control unit that may extend or retract independently, such that fine adjustment of the angular relationship between the excavation direction of the excavation apparatus and the central axis of the cross passage may be achieved by adjusting the stroke of the different force transmission pull rods 12, angle adjusting unit thereby can be cancelled. However, it will be appreciated that the angle adjusting unit may also be kept to provide an auxiliary angle adjustment function or an auxiliary drive function. Preferably, the force transmission pull rod 12 may be provided as an expandable and retractable multi-section structure. It is also possible to adjust the driving force by adjusting the number of force transmission pull rods 12.

[00112] It will be appreciated that, in an embodiment where the force transmission pull rod 12 is configured as an unpowered pull rod, the reaction frame 11 always remains at a fixed position. In an embodiment where the force transmission pull rod 12 is configured as a powered pull rod, the reaction frame 11 reciprocates along the central axis of the cross passage as the force transmission pull rod 12 provides the driving force. Preferably, as shown in FIG. 4, the jacking system 100 is provided with a slide rail 15, which may be made of a rigid material such as steel, and fixedly disposed and extend along the central axis of the cross passage. The reaction frame 11 is movable along the slide rail 15, and the slide rail 15 provides transverse limitation and longitudinal guidance. The reaction frame 11 and the slide rail 15 may achieve guidance and position limitation via cooperation of a protrusion and a sliding groove. For example, the bottom of the reaction frame 11 is provided with a recess as a sliding groove, and the slide rail 15 is received in the recess as a protrusion. Alternatively, the slide rail 11 may be provided with a sliding groove extending along the central axis of the cross passage, while the reaction

frame 11 is provided with a corresponding protrusion. The fitting cross-sections of the sliding groove and the protrusion may be annular, circular, rectangular, etc.

[00113] Further referring to FIG. 1 through FIG. 3, the starting end of the cross passage is preferably provided with a starting casing 13 which is fixedly connected to the main tunnel segment. The fixed connection may be embedding, welding, bolting, sleeve connection, etc. Further, an end of the force transmission pull rod 12 facing the cross passage may be connected to the starting casing 13. In other words, the force transmission pull rod 12 indirectly connects the reaction frame 11 to the main tunnel segment through the starting casing 13. Certainly, in other embodiments, the force transmission pull rod 12 may also be directly connected to the main tunnel segment. Alternatively, it is also possible that part of the force transmission pull rod 12 is connected to the main tunnel segment and part of the force transmission pull rod 12 is connected to the starting casing 13.

[00114] Preferably, the force transmission pull rod 12 is pivotably connected to the starting casing 13 or the main tunnel segment by means of a coupling device, wherein a pivot axis is perpendicular to a length direction of the force transmission pull rod 12. And/or the force transmission pull rod 12 and the reaction frame 11 may also be connected in the same manner via the coupling device. The coupling means may specifically be a pin and a structure fitting with the pin. In addition, the pin may be provided in a removable manner such that the force transmission pull rod 12 is removable from the starting casing 13 or the main tunnel segment and/or from the reaction frame 11. Such a connection manner may be used to adjust the relative position between the jacking system and the main tunnel, fit the design angle, and facilitate normal operations of the excavation apparatus and the jacking system.

[00115] Specifically, as shown in FIG. 1 through FIG. 3, a structure that fits the pin may be a fixedly-arranged mounting base 16. The mounting base 16 and one end of the force transmission pull rod 12 each has a mounting hole through which the pin passes. Preferably, the mounting base 16 comprises two spaced-apart side walls having mounting holes aligned with each other. The end of the force transmission pull rod 12 is received in a space between the two side walls and then the pin passes through the respective mounting holes to achieve the pivotable connection of the force transmission pull rod 12. It will be appreciated that the force transmission pull rod 12 may be removed by removing the pin from the mounting holes. Depending on the connection position of the force transmission pull rod 12, the mounting base 16 may be arranged at different positions. For example, in the embodiment where the force transmission pull rod 12 is connected to the starting casing 13, the mounting base 16 is fixed to

the outside of the starting casing 13; in embodiments where the force transmission pull rod 12 is coupled to the main tunnel segment, the mounting base 16 is secured to the main tunnel segment. The mount 16 may also be fixed to the reaction frame 11 when the force transmission pull rod 12 is pivotally connected to the reaction frame 11.

[00116] In addition, preferably, as shown in FIG. 14, the end of the force transmission pull rod 12 for pivotal connection is provided with a fine adjustment structure 121. The fine adjustment structure 121 is movably arranged to finely adjust the posture of the force transmission pull rod 12 in a manner of deflection relative to the pivot axis. Specifically, the fine adjustment structure 121 may have an oblate shape, and a mounting hole 122 passes through the fine adjustment structure 121 in an axial direction of the oblate shape, and an outwardly-projecting drum-shaped surface is formed on an outer circumferential surface about the axial direction of the mounting hole 122. That is, in the axial direction, a radial dimension of a central portion of the oblate shape is larger than that of both ends. Such a structure allows the force transmission pull rod 12 to deflect slightly within a certain range relative to the pivot axis while allowing the force transmission pull rod 12 to pivot about the pivot axis, thereby enabling the fine adjustment of the force transmission pull rod 12.

[00117] As shown in FIG. 15 through FIG. 17, in some embodiments, the force transmission member of the jacking system 100 is configured as a barrel-shaped structure 12', such as a cylindrical structure. It may be appreciated that in addition to being circular, the cross-section of the barrel-shaped l structure 12' perpendicular to its axial direction may also be in other shapes, such as rectangular, elliptical, etc. The force transmission member constructed as a barrel-shaped structure is similar to the above-mentioned unpowered pull rod, and it only transmits a supporting force without providing any driving force or pushing force. When such a force transmission member is used in pipe jacking construction, the driving force for advance may be provided by the jacking drive unit 14 on the reaction frame.

[00118] The barrel-shaped structure 12' is connected at both axial ends to the reaction frame 11 and the segment of the main tunnel 1 surrounding the starting end of the cross passage, respectively, in order to achieve the function of transmitting the supporting force. The barrel-shaped structure 12' may be directly connected to the main tunnel segment on the side corresponding to the main tunnel segment. It will be appreciated that the main tunnel segment designed to be cut to form the cross passage may comprise a specially-designed steel structure to increase the strength. The barrel-shaped structure 12' may preferably employ a steel structure. The barrel-shaped structure 12' may thus be connected directly to the main tunnel

segment by for example welding. Preferably, the end of the barrel-shaped structure 12' toward the starting end of the cross passage is configured in the shape of a space curve to conform to an arcuate shape of the corresponding main tunnel segment. This facilitates connection of the barrel-shaped structure 12' to the main tunnel segment at any desired position in the circumferential direction of the barrel-shaped structure 12'. In order to ensure the connection strength, it is preferable that the connection be made continuously in the entire circumferential direction of the barrel-shaped structure 12'. In addition, other connections, such as bolting, riveting, and the like, may also be used, alone or in combination, in the connection of the barrel-shaped structure 12' to the main tunnel segment.

[00119] Preferably, the starting end of the cross passage may be provided with the starting casing 13, and the end of the barrel-shaped structure 12' facing the cross passage may be connected to the starting casing 13. In other words, the barrel-shaped structure 12' indirectly connects the reaction frame 11 to the main tunnel segment through the starting casing 13. At this time, only one end of the starting casing 13 connected to the main tunnel segment needs to be configured as a space curve shape for fitting with the arc shape, while the other end of the starting casing 13 connected to the barrel-shaped structure 12' can be configured as a common planar circular shape or other planar structure (depending on the shapes of the two perpendicular to the axial cross section). Therefore, special design is unnecessary for the barrel-shaped structure 12', so that the structural design and production are simple. It will be appreciated that connection means such as welding, bolting and riveting may likewise be used alone or in combination in the connection of the barrel-shaped structure 12' to the starting casing 13.

[00120] Preferably, the barrel-shaped structure 12' may be constructed as a one-piece structure. That is to say, the barrel-shaped structure 12' is an integral member, which reduces the number of parts of the jacking system, thereby reducing the assembling steps and improving the integration degree of the jacking system. Furthermore, the integrally formed barrel-shaped structure 12' can reduce the degree of freedom in mounting the reaction frame 11 with respect to the main tunnel segment, and may effectively reduce the error accumulation as compared with the connection of the plurality of separate members. In other embodiments, the barrel-shaped structure 12' may also be assembled from at least two separate structures, which may reduce difficulty in processing, transportation, storage, etc. due to the excessively large overall size of the barrel-shaped structure 12'. The at least two separate structures may preferably be symmetrical structures with respect to the axis of the barrel-shaped structure 12' or may be small cylindrical structures 12' segmented along the axis of the barrel-shaped structure 12'.

Preferably, the separate structures are identical to each other. In this way, the separate structures are replaceable with each other, there is no specific assembling position, and the possibility of occurrence of the mounting errors may be reduced.

[00121] Preferably, both ends of the barrel-shaped structure 12' each are provided with a flange 121' extending generally radially outwardly of the barrel-shaped structure 12'. The barrel-shaped structure 12' is connected to the reaction frame 11 and the main tunnel segment or starting casing 13 by the flanges 121'. A similar flange 131 may also be provided at the end of the starting casing 13 when the barrel-shaped structure 12' is connected to the starting casing 13. In this manner, the flanges facilitate rapid alignment of the starting casing 13 with the barrel-shaped structure 12' upon assembling, and the flanges may increase the contact area of the connection position, facilitate increasing the connection strength, and reduce stresses resulting from the connection.

[00122] Furthermore, the barrel-shaped structure 12' is provided with reinforcing ribs 123' to increase its structural strength. In the illustrated embodiment, the reinforcing ribs 123' are disposed on an outer side of the wall of the barrel-shaped structure 12', preferably extend in the axial direction, and are arrange in a plurality spaced apart along the circumference of the barrel-shaped structure 12'. It will be appreciated that in other embodiments, the reinforcing ribs 123' may be configured in other forms, e.g., extend circumferentially, or may be set as reinforcing ribs extending crisscross circumferentially and axially, respectively, etc.

[00123] A material delivery hole 122' is also provided in the wall of the barrel-shaped structure 12'. During the excavation of the cross passage, materials such as pipe segments or pipe sections used to assemble the cross passage may be transported to the assembling position through the material delivery hole 122'. Preferably, on a premise of ensuring the structural strength of the barrel-shaped structure 12', the material delivery hole 122' may be provided in a plurality at an interval along the circumference of the barrel-shaped structure 12', the interval preferably being uniform. In this way, the force transmission member constructed as the barrel-shaped structure has a plurality of feasible mounting positions. When the force transmission member is mounted, any of the mounting positions may be satisfied by only making any one of the material delivery holes 122' face towards the material incoming direction, so that quick positioning can be achieved.

[00124] A method of using the jacking system according to the present disclosure to perform excavation construction of a cross passage will now be described with reference to FIG. 5

through FIG. 9.

[00125] In addition to the jacking system 100 and the excavation apparatus 3, the construction of the cross passage by the mechanical method further needs corollary equipment, such as a delivery system 2 for delivering materials shown in FIG. 5. Before excavation, the jacking system 100, the excavation apparatus 3, the starting casing 13 and the delivery system 2 etc. may be combined into a one-piece structure. The complete set of one-piece structure may then be transported to a location in the main tunnel where the cross passage is to be excavated. The whole set of one-piece structure is fixed at the location by using fixing legs and other auxiliary structures.

[00126] Furthermore, the general positional relationship of the starting casing 13, the excavation apparatus 3 and the jacking system 100 is adjusted by a starting adjustment platform to a direction in which excavation is to be performed. Then, the ends of the starting casing 13 and the force transmission pull rod 12 facing the cross passage to be excavated are connected to the main tunnel segment. The force transmission pull rods 12 may all be connected to the starting casing 13 or all be directly connected to the main tunnel segment. Alternatively, the force transmission pull rods 12 may partly be connected to the starting casing 13 and partly be directly connected to the main tunnel segment. In addition, it will be appreciated that the starting casing 13 may also be cancelled in some embodiments.

[00127] Further, the adjustment of the starting direction of the excavation apparatus 3 is accomplished by adjusting the relative positional relationship of the excavation apparatus 3 and the reaction frame 11. An end of the force transmission pull rod 12 facing the reaction frame 11 is connected to the reaction frame 11, and a front end and a rear end of the force transmission pull rod 12 are locked using a fixing mechanism. Thus, the whole set of one-piece structure is connected to the main tunnel 1 to form a fixed whole. The excavation apparatus 3 may then be translated to a planned starting position by an auxiliary device.

[00128] The above-mentioned preparation process is applicable to the jacking system of the embodiment in which the force transmission pull rod 12 is a powered pull rod or an unpowered pull rod, and the construction method by the shield tunneling method and the pipe jacking method.

[00129] Regarding the construction using the shield tunneling method, the subsequent steps thereof are the same for both unpowered pull rod and powered pull rod. After the jacking system 100 has been adjusted to a precise position according to a planned route of the cross

passage to be excavated, a pre-starting auxiliary segment and a steel structure need to be mounted. Then starting excavation is performed, excavation and the assembling of cross passage modular units S (segments) are performed in turn, and the process is repeated performed until the construction of the cross passage is completed. Preferably, as shown in FIG. 4, the reaction frame 11 is provided with a material delivery hole 111 therethrough. The materials such as the cross passage segments to be assembled in the excavation process in the construction by the shield tunneling method may be delivered to the excavation apparatus 3 through the material delivery holes 111.

[00130] Regarding the construction using the pipe jacking method, in a case where the force transmission pull rod 12 is an unpowered pull rod, after the jacking system 100 is adjusted to a precise position according to the planned route of the cross passage to be excavated, the jacking drive unit 14 needs to be mounted and it directly acts on the reaction frame 11. Then the starting excavation is performed with the jacking drive unit 14 abutting against the excavation apparatus 3 to drive the excavation apparatus 3 to advance a distance of one segment (i.e., the modular unit S) in the excavation direction. As compared with the construction by the shield tunneling method, assembling at the position of the jacking system 100 is required in the pipe jacking method, and the segment of the cross passage needs to be delivered in position from the side of the jacking system 100. At this time, at least one of both ends of the force transmission pull rod 12, which interferes with a segment delivery passage, is firstly disconnected and removed. Meanwhile, the jacking drive unit 14 is retracted, and then segments to be assembled are delivered in position through the delivery system 2, and then assembling thereof is completed. Then, the jacking drive unit 14 is extended to closely abut against the segments of the cross passage which have already been assembled. The force transmission pull rods 12 are connected again. The jacking drive unit 14 is again used to drive the excavation apparatus 3 forward a distance of one segment in the excavation direction. The above steps are repeated to complete the excavation and assembling of each segment of the cross passage until the construction of the cross passage is completed.

[00131] Regarding the construction using the pipe jacking method, in a case where the force transmission pull rod 12 is a powered pull rod, after the jacking system 100 being adjusted to a precise position according to the planned route of the cross passage to be excavated, at least one of both ends of the force transmission pull rod 12, which interferes with a segment delivery passage, is firstly disconnected and removed. The removal may be performed by retracting the reverse pulling force hydraulic cylinder or pivoting about the end that remains connected,

to a position that does not interfere with the segment delivery passage. The segment to be assembled is then delivered in position by the delivery system 2 and the assembling is completed. Before the starting excavation is performed, the disconnected force transmission pull rod 12 is connected again, and then the force transmission pull rod 12 is driven to drive the reaction frame 11 to push the assembled cross passage segment and the excavation apparatus 3 forward a distance of one segment in the excavation direction. Then, the force transmission pull rod 12 is driven reversely to drive the reaction frame 11 to retract. The above steps are repeated to complete the excavation and assembling of each segment of the cross passage until the construction of the cross passage is completed.

[00132] Preferably, the starting casing 13 is provided with a retaining device. After the excavation of one segment is completed, this segment may be fixed using the retaining device, and then the force transmission pull rod 12 is driven reversely to retract the reaction frame 11, so as to prevent the segment from being retracted under pressure.

[00133] FIG. 18 shows a jacking system with an integrated reaction frame. In the jacking system 200 shown in FIG. 18, most of the mechanisms are arranged in a manner substantially similar to the arrangement of corresponding mechanisms in the jacking system shown in FIG. 1 and FIG. 2, wherein mechanisms having similar structures or functions are given the same reference numerals. The difference lies in that most of the structures of the hydraulic cylinder constituting the jacking drive unit 24 are provided in an interior of the reaction frame 21, for example, the hydraulic cylinder is provided through the reaction frame 21 in the excavation direction. Meanwhile, the corollary equipment of the jacking drive unit 24 is also provided in the interior of the reaction frame 21, wherein the corollary equipment may be a hydraulic control device, an oil pipe, an oil tank and a valve member, etc.

[00134] Such an arrangement can reduces the size of the reaction frame 21 in the thickness direction, which makes the overall system more integrated, and allows hydraulic cylinders and associated corollary equipment to be pre-installed on the reaction frame 21 in a site such as a workshop having a large space before hoisting the jacking system 200 into the main tunnel, thereby greatly reducing the workload of connecting pipelines and installing hydraulic devices on site in a small space within the main tunnel, and facilitating hoisting and transportation or the like. In addition, the connection and arrangement of the hydraulic pipelines of the jacking drive unit 24 and the control device is very complicated. The environment of the construction site is harsh, and the entire set of hydraulic system of the jacking drive unit 24 exposed to the harsh construction environment is prone to a high failure rate. However, according to the

present embodiment, most parts of the jacking drive unit 24 are hidden in the reaction frame 21, and protected by the reaction frame 21, which reduces of the failure rate and ensures the construction efficiency.

[00135] FIG. 19 shows a perspective view of a hydraulic cylinder constituting the jacking drive unit 24. Here, the hydraulic cylinder comprises a cylinder barrel 241 and a piston 242 telescopically disposed in the cylinder barrel 241. A flange 243 is provided at a front end of the cylinder 241. Accordingly, a mounting hole may be provided in the reaction frame 21, and the cylinder barrel 241 of the hydraulic cylinder extends through the mounting hole so that the flange 243 abuts against the reaction frame 21 in a direction reverse to the excavation direction. Thereby, the reaction frame 21 may provide support for the hydraulic cylinder. Preferably, with reference to FIG. 20, a surface of the reaction frame 21 facing the cross passage may be provided with an annular boss 212 around the mounting hole, and the flange 243 abuts against the boss 212. Furthermore, the flange 243 and the boss 212 may also be securely connected using fasteners 26. The fasteners 26 may be screws or rivets. In some embodiments, the flange may be cancelled and the bottom of the cylinder barrel 241 directly abuts against on the reaction frame 21 so that the reaction frame 21 provides support.

[00136] Similarly, as shown in FIG. 18, the reaction frame 21 is provided with a material delivery hole 211 therethrough. During the construction by the shield tunneling method, materials such as cross passage segments to be assembled may be delivered to the excavation apparatus through the material delivery hole 211. Similar to the embodiment shown in FIG. 1 and FIG. 2, a plurality of hydraulic cylinders may be arranged in a quadrant-symmetrical manner about material delivery hole 211 with respect to the central axis of the cross passage. Preferably, in order to improve the fitting degree between the hydraulic cylinders and the abutted excavation apparatus or modular unit, an annular abutment member (not shown) may be provided, and free ends of the plurality of hydraulic cylinders (i.e., the ends of the pistons 242) are simultaneously connected to the abutment member and abut against the excavation apparatus or modular unit through the abutment member. The abutment member may increase the contact area with the excavation apparatus or modular unit; even if the hydraulic cylinders are not accurately aligned with the excavation apparatus or modular unit, good fitting may be achieved so as to transmit the jacking drive force. In some embodiments, the abutment member may specifically be an annular-shaped jacking member made of, for example, steel.

[00137] As shown in FIG. 21, before the jacking system 200 is hoisted to a starting position of the cross passage, a trolley 27 may be pre-arranged at the starting position. After being moved

into position, the trolley 27 may be supported on the main tunnel segment by its own structures such as support columns and hydraulic support system for affixation. The starting casing 13, reaction frame 21, etc. may then be hoisted into position, and after being installed and fixed, the reaction frame 21 may be supported by the trolley 27. Preferably, the reaction frame 21 is provided with an adjustment unit 28, which may comprise an adjustment drive cylinder for fine adjustment of the position of the reaction frame 21 relative to the trolley 27.

[00138] Preferably, the adjustment unit 28 comprises adjustment drive cylinders arranged in three mutually orthogonal adjustment directions. For example, the adjustment directions may include a fore-and-aft adjustment direction along the excavation direction, an up-and-down adjustment direction along a vertical direction, and a left-and-right adjustment direction orthogonal to the two directions. Accordingly, in the embodiment shown in FIG. 21, the adjustment unit 28 comprises a fore-and-aft adjustment drive cylinder 281, an up-and-down adjustment drive cylinder 282, and a left-and-right adjustment drive cylinder 283. The adjustment drive cylinders may be mounted on the reaction frame 21 and supported on the trolley 27 (e.g., a baffle may be provided at a position of the trolley 27 corresponding to the drive adjustment cylinders to provide support thereto), so as to achieve the relative movement of the reaction frame 21 relative to the trolley 27, thereby achieving fine adjustment of its position.

[00139] Preferably, the reaction frame 21 is provided with left and right projecting lug portions 213 on both sides in the left-and-right adjustment direction, respectively. In this way, the above-described adjustment drives cylinders may be mounted using the lug portions 213, thereby saving the mounting space of the reaction frame 21 exactly facing the cross passage. For example, in the illustrated embodiment, the fore-and-aft adjustment drive cylinder 281 and the up-and-down adjustment drive cylinder 282 are mounted on the lug portions 213. Certainly, the adjustment drive cylinders may be mounted at a main body portion of the reaction frame 21 without affecting the installation of parts, for example, the left-and-right adjustment drive cylinder 283 is provided at a position below the reaction frame 21 and near the side of the reaction frame 21. Also, similar to the hydraulic cylinder of the jacking drive unit 24 for applying the jacking force, the left-and-right adjustment drive cylinder 283 is disposed in the interior of the reaction frame 21.

[00140] Preferably, the adjustment unit 28 may be provided with two sets of adjustment drive cylinders symmetrically in each adjustment direction. The two sets of adjustment drive cylinders are respectively provided on the left and right sides of the reaction frame 21 relative

to the excavation direction. Specifically, the left-and-right adjustment drive cylinder 283 is provided in opposite jacking directions at the left and right sides of the reaction frame 21 so as to provide an adjustment driving force in both leftward and rightward directions, respectively. As for the up-down adjustment drive cylinder 282, it is provided in the same jacking direction on the left and right sides of the reaction frame 21, for example, it is used to jack the reaction frame 21 upward. For the fore-and-aft adjustment drive cylinder 281, in some embodiments, it may include a forward adjustment drive cylinder that pushes the reaction frame 21 toward a direction closer to the starting casing 13 and a rearward adjustment drive cylinder that pushes the reaction frame 21 toward a direction away from the starting casing 13. In other embodiments, the fore-and-aft adjustment drive cylinder 281 may include only a one-way drive cylinder whose cylinder barrel and piston are fixedly connected to the reaction frame 21 and the trolley 27, respectively, to perform both the pushing and pulling adjustment in the fore-and-aft direction.

[00141] It will be appreciated that the adjustment drive cylinders described above are all small-stroke drive cylinders for fine adjustment of the position of the reaction frame 21. Furthermore, the reaction frame 21 requires a larger adjustment amplitude in the front-rear direction than in other two adjustment directions. Therefore, the adjustment unit 28 further comprises an additional adjustment drive cylinder 284 provided in the front-rear direction, which has a larger stroke than that of the front-rear adjustment drive cylinder 281, so that the position of the reaction frame 21 may be adjusted over a larger displacement. The additional adjustment drive cylinder 284 may specifically be a push-pull cylinder whose one end is connected to the reaction frame 21 and the other end may be connected to the trolley 27, for example to a bracket of the trolley 27. Preferably, the additional adjustment drive cylinder 284 may preferably be provided at the bottom so as not to interfere with material delivery and the like during the excavation. Certainly, a large-stroke adjustment drive cylinder similar to the additional adjustment drive cylinder 284 may also be provided in the other direction when the reaction frame 21 has a greater demand for adjustment amplitude in the other direction.

[00142] It will be appreciated that for the cross passage, its one end from which the excavation is started is the starting end and the end at which the excavation is completed may be referred to as a receiving end. FIG. 22 through FIG. 27 show a jacking system particularly suitable for construction of a cross passage communicated with the main channel at its receiving end.

[00143] As shown in FIG. 22 through FIG. 23, the jacking system 300 comprises a reaction frame 31 and a force transmission member composed of a plurality of force transmission pull

rods 32. Wherein the plurality of force transmission pull rods 32 are arranged to be spaced apart from one another in a circumferential direction of the cross passage. Each force transmission pull rod 32 is connected to the reaction frame 31 at one end, and extends through soil layer from the starting end and connected, at the other end, to the main tunnel segment 4 surrounding the receiving end of the cross passage.

[00144] In this way, the reaction frame 31 is used to provide support for the excavation apparatus, and the reaction force of the excavation apparatus acting on the reaction frame 31 is finally transmitted to the main tunnel segment surrounding the receiving end of the cross passage via the force transmission pull rods 32. Thus, a back support system of the reaction frame 31 may be cancelled so that the back space of the reaction frame 31 is released. Particularly, when the starting position is located in another main tunnel, the released back space (i.e., the space between the reaction frame 31 and the main tunnel segment 1 at the starting end on a back side thereof) may allow vehicles, personnel, materials, etc. to pass through the main tunnel, so that a variety of construction processes may be carried out simultaneously, and in particular, a plurality of cross passages may be constructed simultaneously at different positions of the already completed main tunnel, which may greatly shorten the construction period. In addition, regarding the main tunnel at the receiving end, the soil layer may provide support for the main tunnel segment 4 to balance the pulling force of the force transmission pull rod 32 acting on the main tunnel segment 4 surrounding the receiving end of the cross passage, so that deformation of the main tunnel segment 4 connected to the force transmission pull rods 32 due to the pulling force may be avoided.

[00145] Preferably, in the embodiment shown in FIG. 22, the jacking system 10 comprises four groups of force transmission pull rods arranged in a quadrant-symmetrical manner around the central axis of the cross passage, each group consisting of three force transmission pull rods 32. It will be appreciated that in various embodiments, the number of groups of the force transmission pull rods and the number of force transmission pull rods in each group may be flexibly selected depending on the circumstances. In addition, the force transmission pull rods may also act alone, rather than in groups. The force transmission pull rods 32 may be made of a threaded steel (hot-rolled ribbed steel bar) or the like, such as finish-rolled threaded steel. Alternatively, the force transmission pull rods may also be made of other suitable materials in addition to the threaded steel.

[00146] It will be appreciated that the embodiments of FIG. 22 and FIG. 23 only schematically represent of the connecting structure of the force transmission pull rod, and that the dimensions

in the figures do not represent an actual length in an actual construction environment. When the length of the force transmission pull rod 32 itself can satisfy the length of the entire cross passage from the reaction frame 31 to the receiving end, a single full-length structure may be used for each force transmission pull rod 32. However, in some construction environments, when the distance between the starting end and the receiving end is large, the length of a single force transmission pull rod might not meet the requirements of connecting to the main tunnel segment surrounding the receiving end.

[00147] Preferably, as shown in FIG. 23, a plurality of sub-sections 321 may be provided over an entire length range of one force transmission pull rod 32, and adjacent sub-sections 321 may be connected and fixed by connectors 322. The structural strength of the connectors 322 and the connection strength between the connectors 322 and the sub-sections 321 are not lower than the structural strength of each sub-section 321 itself. The connectors 322 and the sub-sections 321 of the force transmission pull rod 32 may be connected and fixed by means of a threaded connection, welding or the like. The fixing manners may be combined, for example, the connectors 322 and the sub-sections 321 may be first connected by means of a threaded connection, and then welded to increase the connection strength. Regarding the sub-sections 321 of the force transmission pull rod 32, its threaded structure for the threaded connection may be a thread structure specially provided at the end thereof by a machining process such as thread rolling. When the finish-rolled threaded steel is used, its ribs of threaded type may be used as the threaded structure connected to the connector 322.

[00148] FIG. 24 shows a force transmission pull rod 32a with another structure. The force transmission pull rod 32a comprises a hollow tube 324 disposed in the soil layer and a force transmission cable 325 connected through the hollow tube 324 to the reaction frame 31 and the main tunnel segment 4 surrounding the receiving end, respectively. In a specific construction, a bore may be firstly drilled, the hollow tube 324 is arranged in the soil layer through the drilled bore, then the force transmission cable 325 passes through the hollow tube 324, and the two ends thereof are respectively connected and fixed to the reaction frame 31 and the main tunnel segment 4 surrounding the receiving end. The hollow tube 324 provides a passageway through which the force transmission cable 325 passes and may function as a sheath for protection. The force transmission cable 325 transmits a pulling force between the reaction frame 31 and the main tunnel segment 4 surrounding the receiving end. The hollow tube 324 may be a steel tube. The force transmission cable 325 may preferably be a structure flexible relative to the hollow tube 324 such as a wire rope, a steel strand, or the like.

[00149] It will be appreciated that the connector 322 described above may also be used with the force transmission pull rod 32a shown in FIG. 24 when the length of the cross passage is long. Here, the connector 322 may connect the hollow tubes 324 on both sides. Since the force transmission cable 325 may be cut to a predetermined length as needed, it may have a full-length structure extending from the reaction frame 31 to the main tunnel segment 4 surrounding the receiving end without having to be provided in sections. Certainly the connectors 322 may also be used to connect the segmented force transmission cable 325 to increase their length, if desired.

[00150] In addition, underground water often exists in soil layer. In order to avoid leakage caused by the force transmission pull rods passing through, sealing means for waterproofing are preferably provided at the positions of the main tunnel segment where the force transmission pull rods passes to avoid seepage of groundwater from the gap between the force transmission pull rods and the main tunnel segment. For example, water-resistant spacers may be provided, or grouting may be performed in the drilled bore through the main tunnel segment to form a waterproof structure.

[00151] Further referring to FIG. 22 and FIG. 23, in the main tunnel located at the receiving end of the cross passage, an inner surface of the main tunnel segment 4 corresponding to the cross passage is provided with a bearing base 5, and a force transmission pull rod 32 (or the force transmission cable 325) passes through the main tunnel segment 4 and is fixedly connected to the bearing base 5. Wherein the bearing base 5 has a large size and contact area, which may disperse and transmit the pulling force of the force transmission pull rod 32 to the main tunnel segment 4, so as to avoid generating stress concentration on the main tunnel segment 4. Preferably, the bearing base 5 has a larger dimension so that at least a part or all of the force transmission pull rods 32 are fixedly connected to the same bearing base 5. In the illustrated embodiment, the bearing base 5 may be a structure provided separately from the main tunnel segment 4, and a side thereof facing the main tunnel segment 4 is configured in a shape capable of conforming to the inner surface of the main tunnel segment 4, such as an outwardly convex arc surface, so as to maximize the contact area between the bearing base 5 and the main tunnel segment 4 and reduce the local pressure therebetween. To ensure sufficient strength, the bearing base 5 may be a steel structure. In other embodiments, the bearing base 5 may also be a structure integrally provided on the main tunnel segment 4, such as a prefabricated reinforced concrete structure or the like.

[00152] As shown in FIG. 23, the force transmission pull rod 32 preferably continues to pass

through the bearing base 5 after passing through the main tunnel segment 4, and a fastener 323 is provided at the end to lock the force transmission pull rod 32 relative to the bearing base 5 against loosening. FIG. 25 through FIG. 27 show different configurations of the fastener 323.

[00153] In the configuration shown in FIG. 25, the fastener 323 is configured as a clip 323a. Accordingly, a distal end of the force transmission pull rod 32 is provided with a slot (not shown) extending substantially perpendicular to the axial direction of the force transmission pull rod 32. After the force transmission pull rod 32 passes through the bearing base 5, the clip 323a engages the slot of the force transmission pull rod 32, so that the force transmission pull rod 32 cannot be retracted, thereby achieving locking. The clip 323a may preferably be secured to the bearing base 5 by additional fasteners 326 such as anti-drop screws or the like. Preferably, the engagement of the clip 323a with the slot is arranged in a symmetrical manner around the axial center of the force transmission pull rod 32.

[00154] In the configuration shown in FIG. 26, the fastener 323 is configured as a locking nut 323b. Accordingly, the distal end of the force transmission pull rod 32 is provided with a threaded structure (not shown). The threaded structure may be a thread-type rib of the finish-rolled steel itself, or may be a thread machined exclusively at the end of the force transmission pull rod 32. After the force transmission pull rod 32 passes through the bearing base 5, the locking nut 323b is threadedly engaged with the threaded structure at the end of the force transmission pull rod 32, so that the force transmission pull rod 32 cannot be retracted. Preferably, a washer 325 may be provided between the locking nut 323b and the bearing base 5 to improve the stability of the locking nut and reduce the possibility of loosening.

[00155] In the configuration shown at FIG. 27, the fastener 323 is configured as a locking pin 323c. Accordingly, the distal end of the force transmission pull rod 32 is provided with a through hole (not shown), which runs through the force transmission pull rod 32 substantially in a radial direction (i.e., a direction perpendicular to the axial direction) of the force transmission pull rod 32. After the force transmission pull rod 32 passing through the bearing base 5, the locking pin 323c passes through the through-hole, and its exposed portion abuts against the bearing base 5, thereby locking the force transmission pull rod 32 relative to the bearing base 5 so that it cannot be retracted.

[00156] It will be appreciated that the jacking system according to the above embodiment is adapted to the excavation of the cross passage communicated with the main tunnel at the receiving end. However, as for the starting end of the cross passage, it may be arranged in

another main tunnel, namely, the cross passage to be excavated is used for contacting two different main tunnels, and may also be applicable to other construction environments other than the main tunnels, for example, the cross passage forms a T-shaped tunnel structure with the main tunnel located at the receiving end thereof, etc.

[00157] FIG. 28 and FIG. 29 further illustrate an embodiment for making full use of the travel space on the back side of the jacking system. Wherein, the structure of the jacking system is substantially the same as the embodiment shown in FIG. 1 and FIG. 2, mechanisms having similar structures or functions have been given the same reference numerals.

[00158] As shown in FIG. 28, the main tunnel 1 is provided with a working platform 46 which is disposed on the main tunnel segment below the jacking system 400 and provides an overall support for structures such as the reaction frame 11. The support by the working platform 46, on one hand, facilitates the alignment of the excavation apparatus with the position of the cross passage to be excavated, and on the other hand, lifts the working surface of the jacking work to a horizontal position of greater radial dimension in the main tunnel, thereby providing a spacious working environment.

[00159] The reaction frame 11 of the jacking system 400 is connected to the main tunnel segment on the side of the reaction frame 11 facing the cross passage by means of a force transmission member, such as a force transmission pull rod 12, thus forming a travel space 45 between the side of the reaction frame 11 away from the cross passage and the segment of the main tunnel 1. A travel platform 451 may be provided within the travel space to provide support for passing vehicles, personnel, materials, etc. The travel platform 451 may be supported on working platform 46 by a supporting member 453. Furthermore, a travel track 452 along the extending direction of the main tunnel may be provided on the travel platform 451. In this manner, the travel track 452 may provide guidance for the movement of vehicles, thereby improving the travel efficiency.

[00160] FIG. 29 shows a modified configuration of the jacking system 400. Therein, in addition to the force transmission pull rod 12, the jacking system 400 comprises an additional force transmission member arranged on the back side of the reaction frame 11 and supported between the reaction frame 11 and the main tunnel segment. In the construction environment of large-diameter tunnels (e.g., 8.0m and above), by adding the additional force transmission member, the jacking system may increase the supporting force provided by the additional force transmission member located at the back side of the reaction frame other than the pulling force

provided by the force transmission member located at the front side of the reaction frame, thereby providing a greater jacking driving force for the excavation apparatus.

[00161] In order to facilitate the formation of the travel space 45, the additional force transmission member may preferably be configured as a plurality of support rods 47 supported between the reaction frame 11 and the main tunnel segment, and arranged discretely substantially around the axis of the cross passage, and provide a substantially uniformly distributed supporting force for the reaction frame 11. The support rod 47 may be a steel rod, or a member made of other materials with sufficient strength, and its structural shape may be flexibly selected as needed. Such a type of support rods only function to transmit the supporting force and do not themselves provide a driving force, and may be referred to as unpowered support rods, that is, the additional force transmission member is an unpowered force transmission member. The connection manner of the support rods 47 to the reaction frame 11 and the main tunnel segment at both ends may include one or a combination of welding, bolting, hinging or riveting, etc. In particular, the connection manner by hinging is employed, which allows fine adjustment of the position of the reaction frame 11 with respect to the tunnel portal of the cross passage, thereby making the excavation position and direction more accurate.

[00162] Preferably, the jacking system 400 is further provided with a bearing base 473, which has a larger size and a side facing the main tunnel segment is provided with a shape close to the inner surface of the main tunnel segment, such as an outwardly convex arc surface. The support rods 47 are connected to a bearing base 473 and interact in a supporting or abutting manner with the main tunnel segment through the bearing base 473. The bearing base 473 may increase the contact area with the main tunnel segment and reduce the local pressure acting on the main tunnel segment. To ensure sufficient strength, the bearing base 473 may be a steel structure. In other embodiments, the bearing base 473 may also be a structure integrally disposed on the main tunnel segment, such as a prefabricated reinforced concrete structure or the like. Alternatively, it is also possible to cancel the bearing base 473 and embed a steel structure in the main tunnel segment to which the support rods 47 are connected or supported.

[00163] Although not shown in the drawings, in some embodiments, the additional force transmission member may also be constructed in the form of a single member, such as a cylindrical structure having both axial ends connected to the reaction frame and the main tunnel segment, respectively. This configuration may reduce the number of parts, thereby reducing the installation process and time, and may effectively reduce the error accumulation compared with a case where the connection is made through a plurality of disperse support rods.

Preferably, the cylindrical structure may be provided with a material delivery hole extending radially therethrough to facilitate material transfer.

[00164] In a further embodiment, the additional force transmission member may also be configured as a device capable of providing a driving force, such as a pneumatically or hydraulically driven pressure cylinder, specifically a hydraulic cylinder, and may therefore be referred to as a powered force transmission member. The powered force transmission members may be connected and arranged in substantially the same manner as the unpowered force transmission members.

[00165] Further, it will be appreciated that when the diameter of the main tunnel is larger (e.g., 8.0m and above), the reaction frame 11 is farther away from the main tunnel segment so that the overall length of the additional force transmission member is also larger. Certainly, it is possible to predetermine the length of the additional force transmission member at the time of engineering design by means of calculation or measurement or the like, so that a single member having a fixed length is connected from the reaction frame 11 to the main tunnel segment in the length direction. Preferably, in a further embodiment, the additional force transmission member may also be provided as a sectional structure comprising two or more sub-sections in the length direction, with adjacent sub-sections in the length direction being connected and secured by a connector. In this way, the length of the additional force transmission member may be flexibly adjusted according to the actual situation at the construction site, which is very advantageous when the installation errors of the jacking system are large. In addition, the small length of each sub-section of the additional force transmission member may also reduce the difficulty in dismantling, storing and transporting.

[00166] Preferably, the plurality of support rods 47 comprises an upper support rod portion 471 and a lower support rod portion 472 which are spaced apart in the up-and-down direction, thereby having sufficient space to form the travel space 45. In this way, the additional force transmission member does not affect the travel. Preferably, the travel platform 451 may be laid over the lower support rod portion 472. Furthermore, in embodiments where the additional force transmission member is configured as a cylindrical structure, the travel space may also be formed by means of the material delivery hole.

[00167] 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 be limited or 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 jacking system for excavation construction of a T-shaped cross passage of a tunnel system, the cross passage communicating with at least one main channel, wherein the jacking system comprises a reaction frame (11) and force transmission member, the force transmission member connects the reaction frame (11) to a main tunnel segment located at a side of the reaction frame (11) facing the cross passage and surrounding a starting end of the cross passage, the reaction frame (11) is used to provide support for an excavation apparatus in an excavation direction, wherein supporting force is transmitted to the main tunnel segment surrounding the starting end of the cross passage via the force transmission member in a way that the force transmission member bears a pulling force.

2. The jacking system according to claim 1, wherein the force transmission member comprises a plurality of force transmission pull rods (12) arranged spaced-apart around a circumferential direction of the cross passage.

3. The jacking system according to claim 2, wherein at least a part of the transfer transmission pull rods (12) are directly connected to the main tunnel segment surrounding the starting end of the cross passage.

4. The jacking system according to claim 2, wherein the starting end of the cross passage is provided with a starting casing (13) connected to the main tunnel segment, at least a part of the force transmission pull rods (12) being connected to the starting casing (13).

5. The jacking system according to claim 2, wherein the force transmission pull rod (12) is configured as an unpowered pull rod.

6. The jacking system according to claim 2, wherein the force transmission pull rod is configured as a powered pull rod capable of providing a driving force.

7. The jacking system according to claim 6, wherein the powered pull rod is a reverse pulling force hydraulic cylinder.

8. The jacking system according to claim 6, wherein each of the powered pull rods has

an independent control unit.

9. The jacking system according to any of claims 6-8, wherein the jacking system further comprises a slide rail (15) extending along a central axis of the cross passage, the reaction frame (11) being movable along the slide rail (15).

10. The jacking system according to claim 2, wherein one end of the force transmission pull rod (12) is pivotally connected to the reaction frame (11), and/or the other end of the force transmission pull rod (12) is pivotally connected to the main tunnel segment or to a starting casing (13) connected to the main tunnel segment.

11. The jacking system according to claim 10, wherein a pivot axis of the force transmission pull rod (12) is perpendicular to the axial direction of the cross passage.

12. The jacking system according to claim 2, wherein one end of the force transmission pull rod (12) is removably connected to the reaction frame (11), and/or the other end of the force transmission pull rod (12) is removably connected to the main tunnel segment or a starting casing (13) connected to the main tunnel segment.

13. The jacking system according to any of claims 10-12, wherein the force transmission pull rod (12) is removably disposed by a coupling device, the coupling device comprising:

a mounting base having two side walls which are opposite and spaced apart, an end of said force transmission pull rod (12) being disposed between the two side walls; and

a pin, wherein the mounting base and an end of the force transmission pull rod (12) are respectively provided with a mounting hole, and the pin passes through the mounting holes of the mounting base and the force transmission pull rod (12).

14. The jacking system according to claim 13, wherein the mounting base is fixedly disposed on the reaction frame (11), or the mounting base is fixed on the main tunnel segment, or the jacking system comprises a starting casing fixedly connected to the main tunnel segment, and the mounting base is fixed on the starting casing.

15. The jacking system according to claim 13, wherein an end of the force transmission

pull rod (12) is provided with a fine adjustment structure, the mounting hole passes through the fine adjustment structure, and the fine adjustment structure has a drum-shaped outwardly-projecting circumferential surface surrounding the mounting hole.

16. The jacking system according to claim 1, wherein the force transmission member is configured as a barrel-shaped structure (12') disposed around the starting end of the cross passage.

17. The jacking system according to claim 16, wherein the barrel-shaped structure (12') is directly connected to the main tunnel segment surrounding the starting end of the cross passage.

18. The jacking system according to claim 16, wherein the starting end of the cross passage is provided with a starting casing (13) connected to the main tunnel segment, the barrel-shaped structure (12') being connected to the starting casing (13).

19. The jacking system according to claim 17 or 18, wherein an axial end of the barrel-shaped structure (12') is provided with a radially outwardly extending flange (121) by which the barrel-shaped structure (12') is connected and secured.

20. The jacking system according to claim 19, wherein a connection manner of the barrel-shaped structure (12') comprises welding, bolting and/or riveting.

21. The jacking system according to claim 16, wherein a sidewall of the barrel-shaped structure (12') is provided with reinforcing ribs (123').

22. The jacking system according to claim 16, wherein a sidewall of the barrel-shaped structure (12') is provided with a material delivery hole therethrough.

23. The jacking system according to claim 16, wherein the barrel-shaped structure (12') is an integrally formed structure or is assembled from at least two separate parts.

24. The jacking system according to claim 23, wherein when the barrel-shaped structure

(12') is assembled from at least two separate parts, the at least two separate parts are identical to each other.

25. The jacking system according to claim 1, wherein a side of the reaction frame (11) facing the cross passage is provided with a jacking drive unit (14) including a plurality of hydraulic cylinders in a quadrant-symmetrical manner and spaced-apart around a central axis of the cross passage.

26. The jacking system according to claim 25, wherein one end of the plurality of hydraulic cylinders is connected to the reaction frame (11) and the other end is connected to an annular abutment member (141) which is used to abut against the excavation apparatus or the segment of the cross passage.

27. The jacking system according to claim 25, wherein the hydraulic cylinders are mounted on the reaction frame (21) and at least partially disposed in an interior of the reaction frame (21).

28. The jacking system according to claim 25, wherein a corollary equipment of the jacking drive unit (24) is disposed in the interior of the reaction frame (21), and the corollary equipment at least comprises a hydraulic control device, an oil pipe, an oil tank and/or a valve.

29. The jacking system according to claim 25, wherein the hydraulic cylinder comprises a cylinder barrel (241) and a piston (242), a front end of the cylinder barrel (241) being provided with a flange (243) and the cylinder barrel (241) abutting against the reaction frame (21) via the flange (243) in a direction opposite to the excavation direction.

30. The jacking system according to claim 29, wherein the flange (243) is connected to the reaction frame (21) by fasteners (26).

31. The jacking system according to claim 29, wherein a surface of the reaction frame (21) is provided with a boss (212) that abuts against the flange (243).

32. The jacking system according to claim 25, wherein the hydraulic cylinder comprises

a cylinder barrel (241) and a piston (242), a bottom of the cylinder barrel (241) abutting against the reaction frame (21).

33. The jacking system according to claim 25, wherein the jacking system further comprises a trolley (27) provided at the starting end, and the reaction frame (21) is supported by the trolley (27), wherein the reaction frame (21) is provided with an adjustment unit (28) for adjusting a relative position between the reaction frame (21) and the trolley (27).

34. The jacking system according to claim 33, wherein the adjustment unit (28) comprises adjustment drive cylinders disposed along three mutually orthogonal adjustment directions, and one of the adjustment directions is an excavation direction.

35. The jacking system according to claim 34, wherein the reaction frame (21) is provided with lug portions (213) on left and right sides of the excavation direction, and at least part of the adjustment drive cylinders are disposed on the lug portions (213).

36. The jacking system according to claim 34, wherein the adjustment unit comprises a first adjustment drive cylinder and a second adjustment drive cylinder at least in the excavation direction, and an adjustment stroke of the second adjustment drive cylinder is greater than that of the first adjustment drive cylinder.

37. The jacking system according to claim 36, wherein the second adjustment drive cylinder is disposed at the bottom of the reaction frame (21).

38. The jacking system according to claim 1, wherein a side of the reaction frame (11) away from the cross passage is provided with a travel space (45) running through in an extension direction of the main tunnel.

39. The jacking system according to claim 38, wherein a travel platform (451) is laid in the travel space (45).

40. The jacking system according to claim 39, wherein the travel platform is provided with a travel track (452) extending in the extension direction of the main tunnel.

41. The jacking system according to claim 39, wherein the jacking system further comprises a working platform (46) disposed on the main tunnel segment below the jacking system, the reaction frame and/or the travel platform (451) being supported on the working platform (46).

42. The jacking system according to claim 38, wherein the jacking system further comprises additional force transmission member connecting the reaction frame (11) to the main tunnel segment at a side of the reaction frame (11) away from the cross passage, a force of the excavation apparatus acting on the reaction frame (11) is transmitted to the main tunnel segment via the force transmission member and the additional force transmission member, and the travel space (45) extends through the additional force transmission member.

43. The jacking system according to claim 42, wherein the additional force transmission member comprises a plurality of support rods (47) arranged about an axis of the cross passage, the plurality of support rods (47) including an upper support rod portion (471) and a lower support rod portion (472), and the travel space (45) being disposed between the upper support rod portion (471) and the lower support rod portion (472).

44. The jacking system according to claim 43, wherein the jacking system further comprises a bearing base (473) having a surface shaped close to the main tunnel segment, and the support rod (47) is coupled to the bearing base (473) and supported on the main tunnel segment by the bearing base (473).

45. The jacking system according to claim 43, wherein the support rod (47) comprises at least two sub-sections disposed in a lengthwise direction, and adjacent sub-sections are detachably connected and fixed to each other by a connector.

46. The jacking system according to claim 1, wherein a material delivery hole (111) running through the reaction frame (11) is disposed at a position of the reaction frame corresponding to the cross passage.

47. A method of using the jacking system according to any of claims 1-46 for excavation

construction of a T-shaped cross passage of a tunnel system, wherein the method comprises:

delivering a jacking system, an excavation apparatus and a corollary equipment to a position where a cross passage is to be excavated, and fixing them;

adjusting positions of the jacking system and the excavation apparatus according to a planned excavation direction;

connecting a reaction frame to a main tunnel segment through a force transmission member;

moving the excavation apparatus to a planned starting position;

excavating and assembling cross passage modular units;

completing the construction of the cross passage.

48. The method according to claim 47, wherein before the step of delivering a jacking system, an excavation apparatus and a corollary equipment to a position where a cross passage is to be excavated, the method further comprises:

combining the corollary equipment, the jacking system and the excavation apparatus into a unitary structure.

49. The method according to claim 47, wherein the corollary equipment comprises a starting casing, and the method further comprises:

connecting the starting casing with the main tunnel segment, and connecting the reaction frame to the starting casing via a force transmission member.

50. The method according to claim 47, wherein the excavation apparatus is a shield tunneling machine, and the method further comprises, prior to the step of excavating and assembling cross passage modular units:

mounting a pre-starting auxiliary segment and a steel structure.

51. The method according to claim 47, wherein the excavation apparatus is a pipe jacking tunneling machine, the force transmission member is an unpowered force transmission pull rod, the cross passage modular unit is a pipe section, and the method further comprises, prior to the step of excavating and assembling cross passage modular units:

mounting a jacking drive unit which acts directly on the reaction frame.

52. The method according to claim 51, wherein the step of excavating and assembling cross passage modular units comprises:

using the pipe jacking machine to complete spatial advancement of the pipe section;

disconnecting and removing at least part of the force transmission pull rods that interfere with a pipe section delivery passage, from the pipe section delivery passage;

retracting the jacking drive unit;

delivering the pipe section to an assembling position to complete assembling;

extending the jacking drive unit out to complete close contact with the assembled pipe section;

restoring the force transmission pull rod to a connected state.

53. The method according to claim 47, wherein the excavation apparatus is the pipe jacking tunneling machine, the force transmission member is a force transmission pull rod capable of providing a driving force, the cross passage modular unit is a pipe section, and the step of excavating and assembling cross passage modular units comprises:

disconnecting and removing the force transmission pull rods that interfere with a pipe section delivery passage, from the pipe section delivery passage;

delivering the pipe section to an assembling position to complete assembling;

restoring the force transmission pull rod to a connected state;

driving the force transmission pull rod to push the pipe jacking method tunneling machine forward via the reaction frame to complete the excavation of the pipe section;

driving the force transmission pull rod reversely to retract the reaction frame.

54. The method according to claim 53, wherein before the step of driving the force transmission pull rod reversely to retract the reaction frame, the method comprises:

fixing a pipe section closest to the reaction frame by a retaining device.

55. A jacking system for excavation construction of a T-shaped cross passage of a tunnel system, the cross passage communicating with a main tunnel at least at a receiving end in an excavation direction, wherein the jacking system comprises a reaction frame (31) and a plurality of force transmission pull rods (32), an end of the force transmission pull rod (32) is connected to the reaction frame (31), the other end of the transmission pull rod passes through a soil layer and is connected to a main tunnel segment (4) surrounding the receiving end of the cross

passage, the reaction frame (31) is used to provide support for an excavation apparatus in an excavation direction, wherein a supporting force is transmitted to the main tunnel segment (4) surrounding the receiving end of the cross passage via the force transmission pull rods (32).

56. The jacking system according to claim 55, wherein an inner surface of the main tunnel segment (4) surrounding the receiving end of the cross passage is provided with a bearing base (5), and the force transmission pull rods (32) pass through the main tunnel segment (4) and are connected to the bearing base (5).

57. The jacking system according to claim 56, wherein the bearing base (5) is a structure that is separate from the main tunnel segment (4) and has sides shaped close to an inner surface of the main tunnel segment (4).

58. The jacking system according to claim 57, wherein the bearing base (5) is a steel structure.

59. The jacking system according to claim 56, wherein the bearing base (5) is a prefabricated reinforced concrete structure integrally disposed with the main tunnel segment (4).

60. The jacking system according to claim 56, wherein an end of the force transmission pull rod (32) passes through the bearing base (5) and is locked with fasteners (323).

61. The jacking system according to claim 60, wherein the end of the force transmission pull rod (32) is provided with a slot perpendicular to an axial direction thereof, and the fastener (323) is configured as a clip (323a) fixed on the bearing base (5), and the clip (323a) is snap-fitted with the slot.

62. The jacking system according to claim 60, wherein the end of the force transmission pull rod (32) is provided with a threaded structure, and the fastener (323) is configured as a locking nut (323b) that threadably engages the threaded structure.

63. The jacking system according to claim 62, wherein a washer is disposed between

the locking nut (323b) and the bearing base (5).

64. The jacking system according to claim 60, wherein the end of the force transmission pull rod (32) is provided with a through hole extending therethrough in a direction perpendicular to its own axial direction, and the fastener (323) is configured as a locking pin (323c) extending through the through hole.

65. The jacking system according to claim 56, wherein a plurality of the force transmission pull rods (32) are connected to the same bearing base (5).

66. The jacking system according to claim 55, wherein each pull rod comprises a plurality of sub-sections (321) arranged in an axial direction thereof, with adjacent sub-sections (321) being connected and secured by a connector (322).

67. The jacking system according to claim 66, wherein a structural strength of the connector (322) is not lower than that of the sub-sections (321).

68. The jacking system according to claim 55, wherein the force transmission pull rod comprises a hollow tube (324) and a force transmission cable (325) passing through the hollow tube (324), wherein the hollow tube (324) is disposed in the soil layer, and the force transmission cable (325) is configured to connect with the reaction frame (31) and the main tunnel segment (4) surrounding the receiving end of the cross passage.

69. The jacking system according to claim 55, wherein the force transmission pull rod (32) is made of threaded steel.

70. The jacking system according to claim 55, wherein a sealing structure for waterproofing is provided at a position of the main tunnel segment (4) where the force transmission pull rod (32) passes.