This invention relates to a tunnel-boring machine, and particularly a machine of the type which performs its boring function by the action of wedge-shaped cutters which are presented on the front surface of a rotary cutting head to produce closely spaced concentric kerfs in the rock face of the tunnel being bored, the wedge shape of the cutters creating progressively increasing compressive forces on the rock between the kerfs to cause fracturing thereof. A mounting body lying to the immediate rear of the head provides a rotary journal for the head. Such body carries electric motors for driving the head, and also centers the head by means of shoes which slide along the walls of the tunnel. A trunk rigid with the body extends rearwardly therefrom. The trunk, while a boring operation is in progress, receives a slip journal from a steering carriage, which is localized by wall-gripping shoes against motion endwise to the tunnel while allowing for adjusting freedoms in directions other than said endwise motion.

A machine of the above-described type is illustrated and described in pending application for Letters Patent of the United States filed Mar. 18, 1963, Ser. No. 265,812 now Patent No. 3,203,737. Such machine was engineered, however, for the boring of tunnels of quite large diameter, 16 foot for example, and the cross-section thereof allows considerable liberty in the design and placement of the machine's structural parts. A tunnel of, say, 7-foot diameter is considerably more restricted. A machine for boring a 7 foot tunnel must be more compact than one for a 9 foot tunnel. If adjusting freedoms comparable to those of the larger machine are to be provided, the mechanism therefore must operate within a compass giving full consideration to the space needs, for other necessary parts of a boring machine require. These mechanisms should, moreover, be equally as rugged as those of the larger machine, and admit of being operated with a minimum of attention.

Having the foregoing in mind, it is a principal object of the present invention to provide a machine of perfected design permitting full adjusting freedoms and one which, while applicable to the boring of a large-diameter tunnel, peculiarly adapts itself to tunnels of relatively small diameter.

It is a further and important object to provide a tunnel-boring machine of an articulated nature so that connecting sections can swing, one relative to another, and thus permit the machine to negotiate curves the minimum arc of which is limited only by the length of a single one of the articulating sections rather than by the overall length of the machine.

These and other more particular objects and advantages will appear and be understood in course of the following description and claims, the invention consisting in the novel construction and in the adaptation and combination of parts hereinafter described and claimed.

In the accompanying drawings:

FIGURE 1 is a fragmentary side elevational view illustrating a tunnel-boring machine embodying preferred teachings of the present invention.

FIGURE 2 is a fragmentary longitudinal vertical sectional view thereof drawn to an enlarged scale on line 2—2 of FIG. 3.

FIGURE 3 is a transverse vertical sectional view on line 3—3 of FIG. 1, employing the same scale as that of FIG. 2, and representing in phantom the main body of the machine on which the rotary cutting head is journaled.

FIGURE 4 is a fragmentary top plan view of the machine.

FIGURE 5 is a fragmentary horizontal sectional view on line 5—5 of FIG. 1, with the scale larger than that of FIG. 1 but smaller than the scale of FIGS. 2 through 4, inclusive.

FIG. 6 is a fragmentary longitudinal vertical sectional view on line 6—6 of FIG. 5; and

FIGURE 7 is a fragmentary transverse vertical sectional view on line 7—7 of FIG. 1.

Referring to said drawings, the numeral 20 generally denotes the main frame of the machine, and 21 the cutting head journaled for rotation upon the frame at the extreme front end of the latter. The head has a multiplicity of cutting wheels mounted upon its front face, and about the periphery at circumferentially spaced intervals presents scoop buckets 22. For simplicity in illustration, only a single "wedge" cutting wheel 23 and a single "gauge" cutting wheel 24 are shown. The scoop buckets have a mouth facing toward the direction of travel of the bucket as the head rotates, and a lip extends forwardly from the mouth to scoop into the mouth rock fragments and other debris cut from the end wall of the tunnel. Each of the buckets has an inner opening and at the upper limit of travel the contents of the bucket are dumped through this opening onto the forward end of the upper run of a power-driven endless conveyor 26. A frame-work 27 supports the conveyor, locating the latter so that the same rises on a moderate incline from said forward receiving end to a rear discharge end whereat the conveyed matter is delivered into a 3-sided bin 28 having for its floor the forward end on a second power-driven endless conveyor 30 with discharges at the extreme rear end of the machine. Such second or tail conveyor receives its support from an afterbody attached as a substantial trailer to a trunk 32 extending rearwardly as a rigid prolongation of the main frame. The structural nature of said afterbody and the manner of its attachment will be hereinafter described.

The main frame is generally cylindrical and at diametrically opposite sides carries a respective one of two electric motors 33. Pinions driven from these motors mesh a bull gear to impart rotary motion to the cutting head. The main frame also carries four guide shoes 34—located at the top, the bottom, and the two sides—adapted to have slide contact with the wall of the tunnel as a boring operation proceeds, for maintaining the head in centered relation to the tunnel. These shoes are mounted for radical movement by sets of parallel-motion links 35, and are set in radically adjusted positions by double-acting hydraulic jacks 36.

The trunk 32 is a fabricated structure comprised of two paralleling beams rigidly joined by crosswebs. Longitudinal ribs 37 flush with the top face project laterally as shoulders from the outer face of each of the beams. The function of the trunk is to steer the head and this is accomplished by shifting the after end of the trunk. The trunk lies parallel with the rotary axis of the head, being offset below such axis to provide space in the central area of the tunnel for a steering assembly. The steering assembly includes a steering box 40 providing for the trunk a slide-way which constrains the trunk to travel a guided linear path which is fixed in relation to the box. The box is suspended from a carriage 41. Through the mechanism of this suspension and the mounting of the carriage from anchoring shoes 42 which
grip the tunnel wall at diametrically opposite sides thereof. The box admits to a plurality of adjusting freedoms, and namely shifting motions transversely and vertically of the tunnel and rolling motions about axes longitudinal to the tunnel. By these freedoms said guided travel path may be altered between a normal position occupied when a straight section of tunnel is being bored and positions angled in selectively variable degrees with respect thereto. Double-acting hydraulic jacks permit the adjustments to be made while a cut is in progress.

The walls-engaging outer faces of the anchoring shoes 42 are generally rectangular in plan configuration, and have projecting spikes 43 for augmenting the wall purchase. When viewed from an end said outer faces are convex to conform to the curvature of the tunnel wall, and as a compensation to wall irregularities each shoe is so universally attached to a related mounting stem that the shoe can rock about both a longitudinally extending horizontal axis and a vertical axis. Each stem presents twin cylindrical piston elements 44 extending as parallel branches from a shoulder part 45. These two sets of pistons are journalled in the main body 41 for opposing slide motion in a direction transverse to the tunnel.

The slide axes of the pistons 44 coincide as between the two shoes. The respective planes occupied by said horizontal and vertical rocker axes also coincide as between the two shoes. For said universal rocker movement longitudinally spaced sockets are provided at the rear of the shoe. A knuckle 46 has stub ends 48 pivoted in these sockets for wrist movement about a longitudinal axis located substantially on the longitudinal median plane of the shoe. Auxiliaries-trunnion sleeves 47 hold the stubs against dislodgment when the shoes are not pressing against a tunnel wall. The shoulder 45 presents an outwardly extending yoke which straddles the top and bottom faces of the knuckle, and a pivot pin 50 connects the arms 51 of the yoke to the knuckle for wrist motion of the knuckle about a vertical axis.

Spring-loaded pins 53 evenly spaced in two horizontal rows one above and the other below the yoke and extending equal distances fore and aft of the transverse vertical plane occupied by the pin 50 exerts balancing thrust from the shoulder 45 to the shoe 42 to normally hold the shoe in a plane normal to the common slide axis of the two stems. The springs, denoted by 54, occupy pockets 55 which are provided in the shoulder part and exert their thrust upon flanges which are formed upon the pins, yielding by urging the latter to bear against a keeper plate 56 which is fixedly secured to the shoulder.

The carriage 41 is or may be in the form of an elongated right prism placed so that its major axis extends transversely of the machine. Parallel through-bore 57 placed symmetrical to the longitudinal median line of the prism provide the slide journals for the twin pistons 44. The through-bore with the pistons which slide therein function as the components of a pair of double-acting hydraulic jacks exerting opposing thrust forces through the shoes upon the walls of the tunnel. Hydraulically fluid is supplied under pressure to and dumped from the cylinders 57 of the jack through drill-holes 58 and 59. The carriage is shiftable in the manner of a cross-head into selected positions adjusted transversely of the tunnel by means of a pair of double-acting hydraulic jacks 60 extending transversely in an approximate horizontal plane between the carriage and the shoulder 58 of one of the shoe stems, connecting with suitable mounting lugs by pivot pins 61 and 62.

The steering box 40 has a U-shape when viewed from the side. Legs 63 of such U overlie the front and the back faces of the carriage with a moderate spacing therebetween. A multiplicity of springs occupy this space, and perform a balance function in much the same manner as the springs 54, to normally maintain the carriage in a position centered between the legs. A pair of upper and lower springs 64 are placed at the center of the space, and vertical rows of closely spaced springs 69 are located adjacent each of the two ends. Springs 64 surround the stem of a headed pin 65 within a pocket formed in the carriage, and exert outward thrust upon a flange of the stem to yieldingly press the exposed head of the pin against the flat surface of a boss 66 presented by the concerned leg of the steering box. A keeper for the pins 65 is fixedly attached to the carriage. Easing action of the stems against the floor of the concerned pockets limit the degree to which the pins 65 can be depressed.

The springs 69 each occupy a cylindrical pocket which extends front to back through the concerned leg of the steering box, each surrounding a respective rod 68. Inner ends of the several springs 69 in each vertical row seat in a respective socket presented by a flat-faced vertical bar 70. The rods 68 have their inner ends pinned to the bar and have a nut 71 threaded upon the exposed outer end. Springs 69 take their purchase against a keeper plate 72 which is secured to the legs 63. Bars 70 perform act as spring-pressed bumpers, bearing against slide faces which are presented by the carriage.

The cross-arm 73 of the steering box has an inverted U-shape when viewed from the end to produce a downward-facing channel 74 which serves to receive for the trunk. Internal slippers 75 and 76 secured by cap-screws to the sides and top of the channel produce the slide surfaces upon which the trunk bears, the slippers 77 being lipped to catch upon the ribs 37 of the trunk. The steering box is raised, lowering, and rolling motions by a radius arm 80 extending longitudinally of the carriage from the box to the carriage on substantially the median line of the carriage. With the jack 77, said linking radius arm 80 has ball-joint end connections.

It will be understood that the carriage and the steering box function only to locate the axis along which the main frame of the machine slides as a cutting operation proceeds, and to resist torque loads created by the rotary motion of the cutting head. No thrust loads exerted by the rock face on the rotary cutting head are carried back through the trunk. Those thrust forces are passed from the head through suitable bearing supports (not shown) into the head portion of the main frame, and thence are carried directly to the wall-gripping shoes through two pairs of horizontal longitudinally extending double-acting hydraulic thrust jacks 81. One such pair is located at each of the two sides of the machine. The thrust jacks have ball-joint end connections.

The trunk, at its rear end, is surmounted by a strap 82. The overhanging rear end of the framework 27 which supports the endless conveyor 26 seats on and is rigidly secured to this stand.

The afore-mentioned afterbody which is attached as a trailer to the extreme rear end of the trunk is a 2-deck structure and receives a mounting from a bracket 83 bolted to said trunk. The two decks are each connected to said bracket for swing motions independently of one another about both vertical and transverse horizontal axes. In the instance of each deck, the vertical swing motion is about the center of a respective transverse horizontal hinge pin as an axis, and the horizontal swing motion is about the center of a respective king pin as an axis. The hinge pin 85 for the upper deck is mounted through depending arms 87 of a terminal yoke. The hinge pin lodges in a rearwardly facing slot provided by an upper-level fork 88 of the bracket 83. The related king pin 89 traverses the hinge pin at the substantial center thereof and has upper and lower ends journaled in the arms of the fork. A substantial lower mounting is provided for the lower deck 90, with
the hinge pin and the king pin being in this instance denoted by 91 and 92, respectively, and having the fork 93 therefor stepped below and in forwardly spaced relation to the upper-level fork.

The lower deck 90 has skid shoes 94 projecting diagonally downwardly from each side at the rear end to sustain such rear end from the side walls of the tunnel. Such lower deck provides a station for the operator, with the necessary controls and gauges for the operation of the machine. A motor-driven pump for the machine's hydraulic system is also mounted upon such lower deck.

The electric power for driving this motor and the motors which rotate the cutting head is carried to the control station by trailing cords. Flexible hoses extend between the control station and the several hydraulic jacks.

The length of the afterbody's lower deck is approximately half that of the upper deck 87. A stand 99 supports the rear end of the lower deck to form a stationary rest for the overhanging rear end of such upper deck. A cross-bar 95 also functions as a sustaining member for said rear end. Hydraulic jacks 96 permit such bar 95 to be raised or lowered, and a double-acting hydraulic jack 97 extending transversely from the bar to a post 98 depending from the upper deck permits the upper deck to be shifted in either lateral direction.

It is thought that the manner in which the machine operates will have been largely apparent from the foregoing description. When the anchor shoes 42 have been retracted from the tunnel wall incident, say, to moving the shoes forward for taking a grip at a new location, the machine is supported by the front-end guide shoes 34 and by a rear foot 100. This rear foot is operated by a hydraulic jack and during working periods of the machine is kept retracted. For said forward movement of the shoes (the present machine being engineered for a 2-foot stroke), the four thrust jacks 81 are retracted. This draws the disengaged shoes ahead, causing the steering box to slide upon the trunk in concert with such advance. Upon reaching the forward limit of this resetting "step," the operator charges pressure fluid into the cylinders 57 of the carriages 41, forcing the pistons outwardly within said cylinders to cause the anchor shoes to be again firmly attached against the tunnel wall.

With the piston now localized relative to the tunnel, the rotary axis of the cutting head may be placed in selected adjusted positions by manipulation of the steering assembly, and namely by operation of the horizontal jacks 60, the vertical jacks 77, and the longitudinal jacks 81, an adjustment of one most commonly dictated a complementing adjustment of the others. These adjustments can be performed either when the machine is stationary or while a cut is in progress. It will be apparent that the hydraulic pressure which exerts outward wall-gripping force upon the anchor shoes is in no wise affected by adjustments given to the carriage causing the latter to slide upon the pistons 44 toward or from either shoe 42. The universal connections at the ends of the radius arms 80 and at the ends of the vertical jacks 77 allow the steering box to cock itself relative to the carriage when adjustments made to the steering assembly locate the slide axis of the trunk in an abnormal condition, or which is to say any condition other than one midway. Between the shoes normal to a transverse vertical plane occupied by the shoes. Should the anchor shoes "creep," circumferentially of the tunnel during the progress of a cut in consequence of the purchase having been taken upon a faulty surface, counter-activation of the two vertical steering jacks 77 brings the steering box back to a level position. It will be understood that each of the vertical jacks 77 may be operated independently of each other and of other independently of the carriage-shifting jacks 60. Thus any compound movement of lateral and vertical movements, within prescribed limits, may be obtained. All thrust forces are passed through the jacks 61 from the main body directly to the anchor shoes. Torque is passed from the trunk into the vertical steering jacks 77.

The trailing afterbody, being hinged for swing motion, permits the machine to negotiate curves of considerably shorter radius than would otherwise be permitted. The machine must have a greater length than machines which are engineered to bore larger tunnels in that space limitations do not permit the operator's station to be located close to the front of the machine.

It is believed that the invention will have been clearly understood from the foregoing detailed description of our now-preferred illustrated embodiment. Changes in the details of construction may be resorted to without departing from the spirit of the invention and it is accordingly our intention that no limitations be implied and that the hereto annexed claims be given the broadest interpretation to which the employed language fairly admits.

What we claim is:

1. In a tunnel-boring machine, a power-driven rotary cutting head, a main body having said head journal-mounted thereon, a trunk extending rearwardly from said body, a box providing a slide-way for the rear end of said trunk, anchor means movable into and out of gripping engagement with the wall of a tunnel being bored, means supporting said box from the anchor means for adjustment of the box both vertically and transversely relative to the anchor means, and a trailing afterbody hinged to the rear end of the trunk.

2. A tunnel-boring machine according to claim 1 in which the hinge connection permits the afterbody to swing in two planes at right angles to one another.

3. A tunnel-boring machine according to claim 1 in which the afterbody supports an operator's platform and controls for the operation of the machine.

4. A tunnel-boring machine according to claim 1 in which the afterbody is comprised of upper and lower sections hinged by their front ends so that each can swing independently of the other both horizontally and vertically, the lower section providing means sustaining the rear end of the upper section in elevated relation to the lower section.

5. A tunnel-boring machine according to claim 4, means being provided for shifting the rear end of the upper section relative to the lower section into selected positions within given ranges of transverse and vertical adjustment.

6. A tunnel-boring machine according to claim 1 in which the trunk and the afterbody respectively support a front and a rear endless conveyor acting as passive carriers for moving fractured rock and other debris from the machine's front end to the extreme rear end thereof.

7. A tunnel-boring machine according to claim 6 in which the front endless conveyor has its receiving front end located at the approximate mid-height of the rotating head so that rock fragments picked up by scoop buckets rotating with the cutting head can be dumped by gravity onto said conveyor, and slopes upwardly from said receiving end to a discharging rear end which overhangs the receiving front end of the rear conveyor, the trunk having a surmounting stand upon its extreme rear end giving support to the rear end of the front conveyor, the box in which said trunk slides lying to the front of the stand.

8. In a tunnel-boring machine, a power-driven rotary cutting head, a main body having said head journal-mounted thereon, anchor means movable into and out of gripping engagement with the wall of a tunnel being bored, operative interconnection between said anchor means and the main body for positioning the main body within the tunnel, and an afterbody hingedly connected in trailing relation the main body for both horizontal and vertical swing motion relative to the main body, said afterbody comprising upper and lower sections having said hinge connection with the main body located...
at the respective front end and being characterized in that each section can swing independently of the other.

9. A tunnel-boring machine according to claim 8 in which the hinge connection comprises a trunnion having its ends journaled for rotation about a transverse horizontal axis in the arms of a yoke fixed to the afterbody, and a king-pin traversing the trunnion midway between said journaled ends of the trunnion and having its own ends journaled for rotation about a vertical axis in the arms of a fork fixed to the main body.

10. A tunnel-boring machine according to claim 9 having means at the rear end of the lower section sustaining the rear end of the upper section in elevated relation thereto.

11. In a tunnel-boring machine, a main body having a rotary cutting head journaled for rotation thereon, a trunk rigid with and extending rearwardly from the body presenting slide faces paralleling the axis of rotation of the head, anchor shoes movable into and out of gripping engagement with the wall of a tunnel being bored at a position spaced a substantial distance to the rear of the head, piston elements attached to and extending inwardly from each of said anchor shoes on a substantially vertical diameter of the tunnel, a block serving as a carriage occupying a position between the shoes and bored from its ends on a coinciding axis to provide cylinders in which the pistons are received, said cylinders forming journals for sliding motion of the carriage endwise to the pistons, means for moving the carriage to and setting the same at selected points within a permitted range of said slide motion, a steering box providing a slide-way for said slide faces of the trunk constraining the trunk to travel along a guided linear path which is fixed in relation to the box, at least two upright arms independently adjustable as to length each supporting a respective one of the two sides of the box from the carriage, and a linking connection between the carriage and box disposed transversely of the tunnel to prescribe a guided path in which the box moves upon adjusting the length of the hanger arms.

12. A tunnel-boring machine according to claim 11 having a trailing afterbody hinged to the extreme rear end of the trunk.

13. A tunnel-boring machine according to claim 11, a matching set of at least two paralleling pistons being attached to each of said shoes.

14. A tunnel-boring machine according to claim 13 in which the co-axial bores for at least one of the two pistons of said sets of pistons are in communication, hydraulic fluid from a pressure source being supplied thereto for forcing the pistons outwardly and responsively pressing the shoes against the tunnel wall.

15. A tunnel-boring machine according to claim 11 in which the means for moving and setting the carriage comprises a double-acting hydraulic jack.

16. A tunnel-boring machine according to claim 11 in which the hanger arms for the steering box are comprised of double-acting hydraulic jacks.

17. A tunnel-boring machine according to claim 11 in which the piston elements are universally attached to the anchor shoes.

18. A tunnel-boring machine according to claim 11 in which the box provides upstanding cheek sections which overlie front and back faces of the carriage in spaced normally parallel relation thereto, and spring-pressed means carried by one and pressing against the other of said normally parallel faces for yieldingly urging said faces into said parallel condition.

19. A tunnel-boring machine according to claim 11 in which the linking connection is a radius arm.

20. A tunnel-boring machine according to claim 11 in which said upright arms are comprised of double-acting hydraulic jacks.

21. A tunnel-boring machine according to claim 11 in which the means for moving and setting the carriage comprises at least one double-acting hydraulic jack extending as a connection between the carriage and one of the anchor shoes.

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