Aug. 14, 1956 J. WOHLMEYER 2,758,825

MACHINE FOR BORING GALLERIES, TUNNELS, CHANNELS AND THE LIKE BY CUTTING ACTION

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Fig. 1

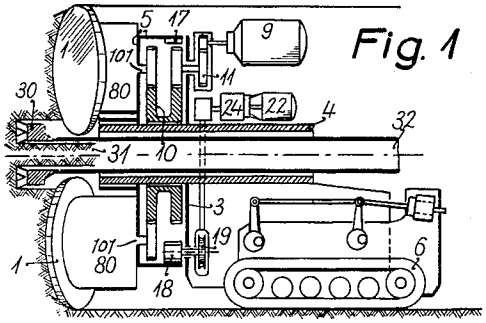


Fig. 2

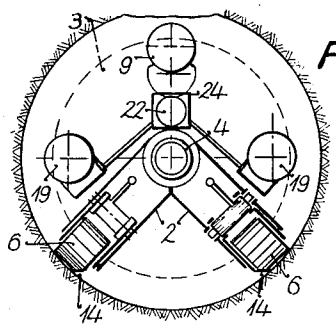


Fig. 3

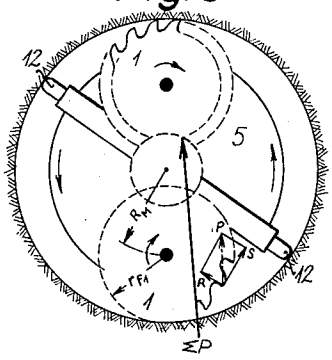


Fig. 4

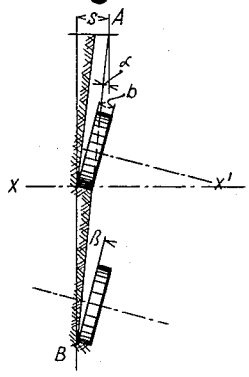


Fig. 5

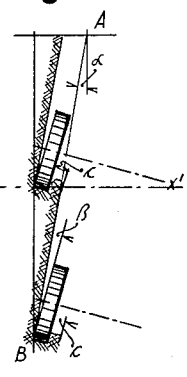


Fig. 6

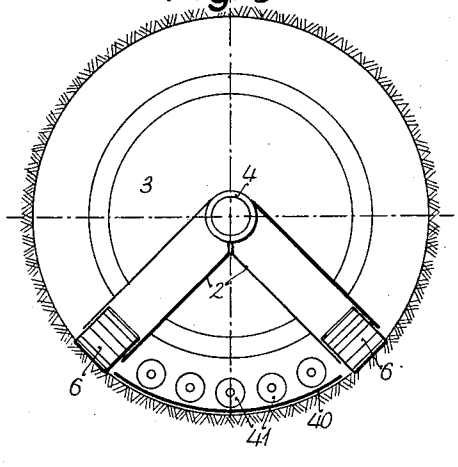
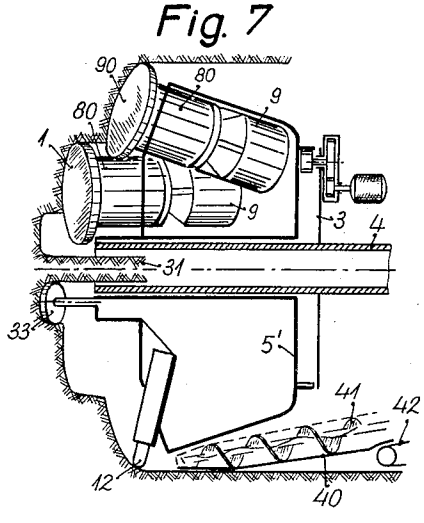


Fig. 7



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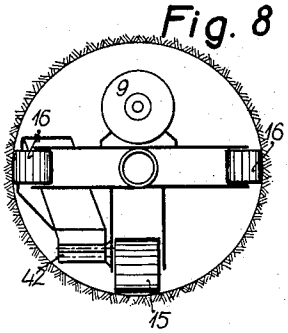
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Fig. 8



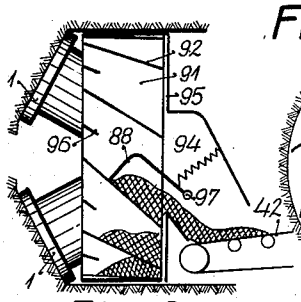


Fig. 9

Fig. 10

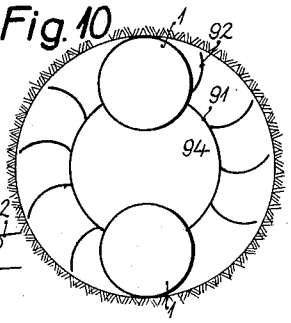


Fig. 11

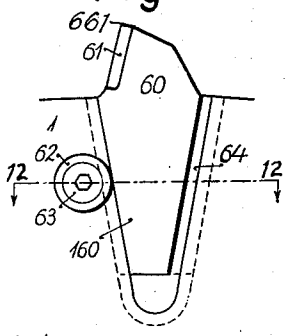


Fig. 12

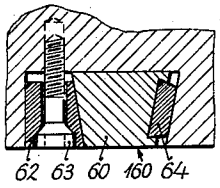


Fig. 13

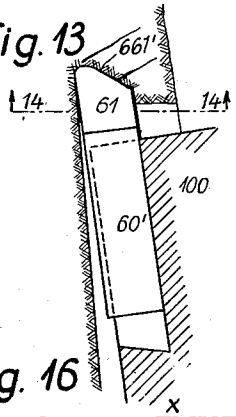
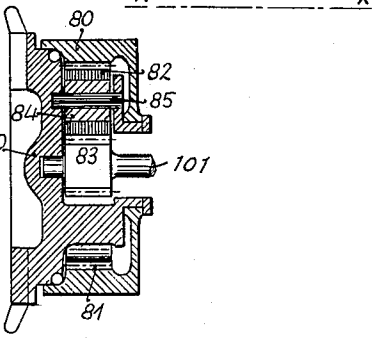


Fig. 16



X'

Fig. 14

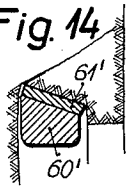


Fig. 15

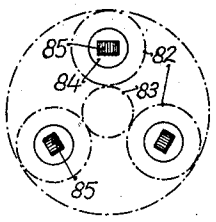


Fig. 18

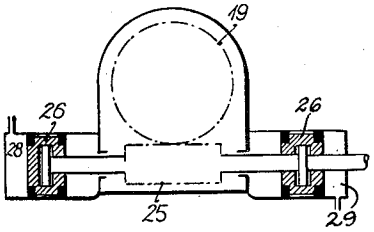
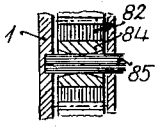


Fig. 17



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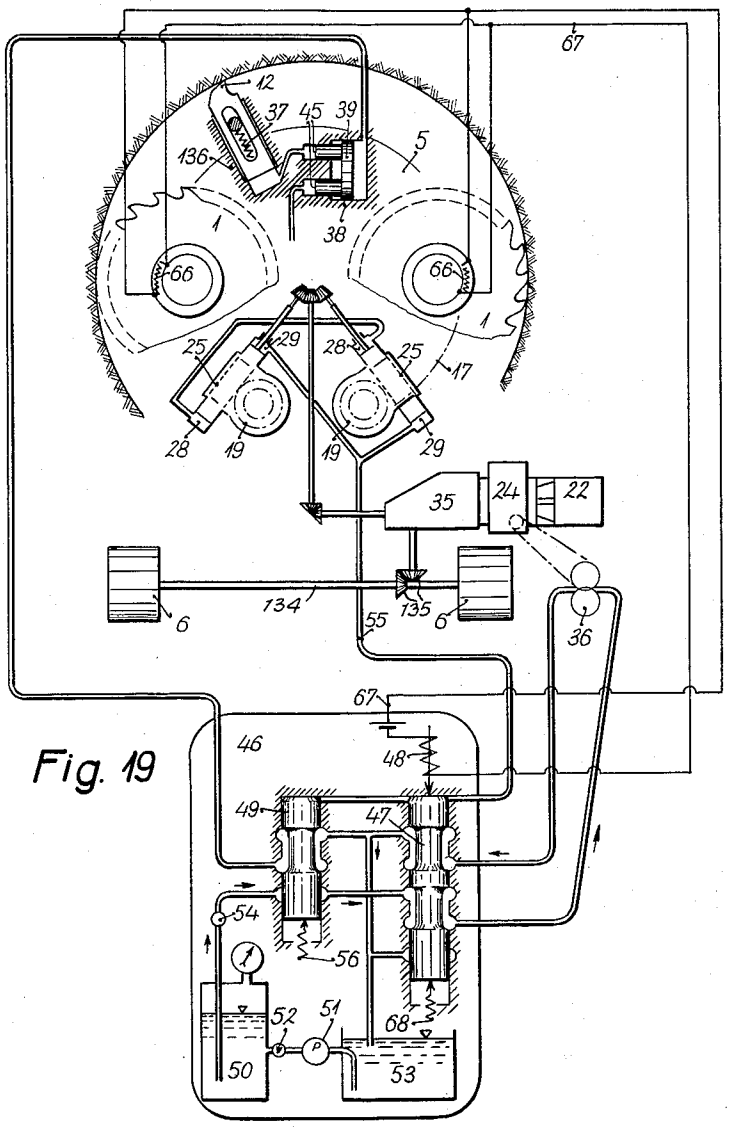


Fig. 19

INVENTOR.
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United States Patent Office 2,758,825 Patented Aug. 14, 1956

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MACHINE FOR BORING GALLERIES, TUNNELS, CHANNELS AND THE LIKE BY CUTTING ACTION

Josef Wohlmeyer, Vienna, Austria

Application March 17, 1952, Serial No. 277,013
Claims priority, application Austria March 29, 1951
12 Claims. (Cl. 262—7)

The invention relates to improvements in tunneling machines for boring tunnels, galleries, channels, and the like by the action of rotating cutters disposed on the end surface of discs known as cutter heads which themselves gyrate in a planetary manner about the axis of the tunnel or the like.

This construction necessarily produces continual crossing of the cycloidal cutting paths of the knives whereby undesirable excessive comminution of the rock material and consequent excessive wear of the knives become unavoidable.

The main disadvantage of these known boring devices is however the axial pressure of the knives against the end face of the gallery, which because of the large number of knives employed and also because of the large contact pressure, necessary more especially in the case of rock, requires forces so large as to be incapable of being supported by the weight of the machine itself. Therefore, the remedy was adopted of sustaining this large contact pressure by support against the walls of the gallery. Such an expedient however necessitates a very heavy and long machine frame which is in two parts. Before each successive step in the work, the rear part had first to be pulled forward again, which rendered necessary a complicated spreading device on the front part.

Moreover it cannot start on a gallery unless a part thereof of a length equal to the considerable length of the machine has already been previously bored out by other previously known boring methods. Because of its great length it canot start a cross cut from a main gallery of normal width.

All these disadvantages are avoided by the invention which consists essentially in the fact that by the knife forces and the cutting pressures there is brought about an automatic pressing of the cutter heads against the material to be bored in the working direction so that the machine need be pressed against the end face of the gallery with only a slight force. Thus it is possible to mount the machine on ordinary self-laying tracks. In addition to being much lighter and more mobile the machine is now capable of being steered and is therefore suitable for boring curved galleries and for moving into side galleries. These objects are essentially attained in accordance with the present invention in that the cutters are acting in a direction approximately tangential to the helical path. To this effect the cutters are arranged on the periphery of the cutter heads, and their knives project substantially radially therefrom and have cutting edges lying in planes going substantially through the rotating axis of the cutter head. They therefore effect the main cutting work not at the front face of the cutter head and in cycloidal paths which cross one another, but at the periphery of the cutter heads and after the manner of cylindrical cutters. In contradistinction to previous constructions, therefore, according to the invention only about half of the blades are engaged at the same time.

The cutter heads are pressed approximately perpendicular to the axis of the gallery in the direction of the

tangents to the planetary path of the cutter heads, by a torque on the rotary plate carrying the cutter heads. Thereby the pressure of the knives against the material to be bored is attained.

If fact, this contact pressure may become so great and dangerous that according to the invention separate means such as brake knives, brake jaws and the like are provided. When the permissible contact pressure is exceeded these means are pressed against the material to be bored, for instance the rock, whereby the contact pressure is reduced to the permissible value. According to the invention these braking members may be brought into action automatically depending on the excess torque which occurs.

If excess load on a cutter head or on individual knives arises, breakages may occur. This localized excess load is most unlikely to be observed in time by the machine operator. According to a further feature of the invention, therefore, the drive of the planetary movement, of the cutter heads and of the self-laying track mechanism is regulated by an automatic control. On the one hand, breakages due to localised excess load on the machine are thereby rendered impossible. On the other hand, this control ensures that the machine will automatically adjust itself to maximum drifting performance.

Embodiments of the invention, chosen by way of example, are illustrated in the accompanying drawings, in which:

Figure 1 is a diagrammatic principal section of a gallery boring machine according to the invention, provided with two cutter heads,

Figure 2 is a rear view thereof in elevation, and

Figure 3 is a front view thereof in elevation.

Figs. 4 and 5 illustrate diagrammatically positions of the cutter heads with two different feeds of the machine relatively to the main axis X—X of the machine.

Fig. 6 is a diagrammatic rear view in elevation of a part of a modified boring machine showing a number of conveyor worms for removal of the detritus.

Fig. 7 is a diagrammatic principal section of the modified embodiment showing additional outer cutter heads and separate small inner cutter heads.

Fig. 8 is a rear view showing a part of the machine with a modified track.

Figs. 9 and 10 show further modified embodiments of the machine for another form of detritus removal, Fig. 9 being a cross-sectional view, and Fig. 10 a diagrammatic view of the conveyor wheel and the cutter heads.

Fig. 11 is a front view of a cutting knife detachably secured in the cutting head.

Fig. 12 is a cross section on the line 12—12 of Fig. 11.

Fig. 13 is a plan view of a modified knife in working position.

Fig. 14 is a section on the line 14—14 of Fig. 13.

Fig. 15 is a diagrammatical illustration of a cutter head, Fig. 16 a cross section through a cutter head of Fig. 15 on a larger scale, and Fig. 17 a detail of a modified construction according to Fig. 16.

Fig. 18 is a diagrammatic section of oil-hydraulic means for ensuring equal loading of worm transmissions for the drive of the rotary plate carrying the cutter heads.

Fig. 19 is a diagrammatic view of an automatic regulation device of the tunneling machine.

The frame (Figs. 1 to 3) consists of a kind of plate disc 3 having a tubular shaft 4 and a rotary plate 5 mounted thereon. The latter carries the cutter-head casing 80 and the brake knives 12. It is driven, through the toothed rim 17, the pinion 18 and the worm drive 19, from the motor 22 through a continuously variable drive 24. The large forces which occur may render necessary the arrangement of a plurality of worm drives, for instance two as shown in Figure 2, uniform loading of which may

be ensured by hydraulic pressure equalization according to Figures 18 and 19.

The knives of the cutterheads have cutting edges each disposed in a plane passing through the rotation axis X' of the respective cutter head and each constituting the intersection of two surfaces one of which is subsanially radial (Figs. 3, 4 and 5).

Driving of the cutter heads 1 provided with stub shafts **101** is effected, through a central gear **10** and a transmission gear **11**, by one or more motors 9 mounted on the frame.

The frame is supported on track-carrying cases which are inclined for instance at 45° and in each of which is guided a complete track mechanism **6** together with its drive. The track mechanism **6** is driven by the motor **22** through the continually variable drive **24**, the transmission means **35** to the gears **135** driving the axle 134 of the track mechanism (Fig. 19). The track members may be provided with bevelled parts **14** (Figure 2) to enable the machine to travel over level ground. In special cases a third displaceable track acting in a vertically upward direction may be provided. Alternatively, it may in some cases be advantageous to provide a single vertical carrying track **15** and two lateral supporting tracks **16**. Such a construction is shown in Figure 8.

According to the invention, the drive of the travelling mechanism is coupled to that of the rotary plate during the boring operation, and has a disengageable fast or high gear for both directions of travel.

For galleries having a large diameter, according to the invention a number of further cutter heads **90** may be disposed on a larger radius outside the inner cutter heads, as shown in Figure 7 which illustrates an embodiment in which the outer cutters and parts of plate 5' are inclined. It may also be advantageous to construct each cutter head together with its transmission casings **80** and motor **9** as a self-contained unit disposed on the rotating plate, as shown in this figure.

According to Figs. 4 and 5 which illustrate diagrammatically the position of the cutter heads relatively to the main axis x—x of the machine; the lines A—B represent the developments of the cutter head paths during a revolution of the rotary plate. They are developments of helices having a pitch angle α and a pitch s which is approximately equal to the width of a cutter multiplied by the number of cutter heads (Fig. 4). In suitable material, according to the invention the feed of the machine may exceed this value considerably, if the undercut width c of rock (Figure 5) comes off in splinters or crumbles away. By this means knife material is saved and also the fragment size of the cut material can be changed.

A boring method of this kind can be considerably improved according to the invention in the manner shown in Figs. 13 and 14 by the illustration of a knife **60** having a hard metal facing **61**. The cutting edge **661**[1] on hard metal facing **61**[1] slopes rearwardly toward the axis of the cutter head **100** Fig. 13). Here, the directions of the knife edges and the kife cutting surfaces of the cutter head **100** have been made such that the crumbling process can be assisted to a great extent. The knife surfaces can also be made curved in order to control or regulate the process to a greater extent. Lastly, it is possible also to provide, in addition to the cutting knives, pressure tools or reaming tools having the shape of a ploughshare or some other curved shape for assisting the desired crumbling processes.

The inclination of the non-cutting surfaces of the cutter heads to the frame tube axis x—x for the machine (Figures 4 and 5) is determined by the pitch angle α of the knife paths nearest the axis. It is made to exceed this angle α by an angle β in order to obtain free cutting.

The inner zone of the gallery is in this instance cut out by separate small cutter heads **33** (Figure 7) or by a central boring head **30** (Figure 1), in order to render the necessary inclination of the cutter heads smaller and at the same time to prevent cutting in a sliding or grinding manner which would cause the knives to wear out very much sooner. In this manner it is possible at the same time to obtain a bore core **31**. The core boring device **30** with the tubular shaft **32** may also have a completely independent drive and by means of a suitable feed device may render possible probing of the masses of rock to be bored.

As is shown in the bottom part of Figure 3, in the manner of operation employed a resultant force ϵP arises as the sum of all knife cutting forces S and back-pressure forces R. This force tends to move the rotary plate in the direction in which it is rotating, i. e. it produces an assisting or additional torque. Since this additional torque may fluctuate very strongly depending on the rock and cutting conditions, according to the invention displaceable brake knives or even brake jaws **12** are provided for compensating this additional torque, which are mounted on the rotary plate **5** or on the cutter head casings **80**. In order to prevent overspeeding of the machine before the brake knives become effective, the drive of the rotary plate 5 is made self-stopping. In Figure 2 it is effected by two worm transmissions **19** equal loading of which is ensured by oil-hydraulic means according to Figure 18. The axial load on the longitudinally moveable worm **25** is transmitted through the piston **26** to the oil in the pressure chambers **28** and **29**, the chambers of all worm units being connected with one another unidirectionally.

In order to render it possible to accommodate in the available space the mechanism transmitting the very large forces driving the cutter heads, according to the invention the first transmission (according to Figures 15 to 17) is formed as an epicyclic gear. Between the internal toothed rim **81** and the cutter-head casing **80** and the driving pinion **83** on the drive shaft **101** run three or four planetary or intermediate pinions **82** which thus distribute the driving force over a corresponding number of teeth. The intermediate wheels **82** are mounted in the correspondingly formed cutter head **1**, their mountings being resilient in the direction of rotation. They rotate on bushes **84** which according to Figure 17 are provided with somewhat rounded recesses by means of which they are supported on laminated plate springs **85** yielding in a tangential direction only. This automatically ensures both even support over the entire tooth width and also approximately equal loading of all intermediate wheels **82**, while at the same time no great precision of manufacture is required.

Securing the cutting knives in a rapidly detachable manner, for instance as shown in Figures 11 and 12, is of great advantage in regard to the efficiency of the boring method according to the invention. The cutting knife **60** is provided with a hard metal facing **61** having a cutting edge **661** parallel to the rotary axis of the cutter head (Fig. 11). The knife **60** has a tapering shank **160** of trapezoidal cross section. This shank fits into a suitable milled recess or groove in the cutter head **1**. The knife is anchored in such a manner that it will not fall out, being frictionally secured by means of a cylinder **62** having a flat inclined surface. This cylinder is subjected to contact pressure by means of a self-securing internal hexagonal screw **63**.

To ensure that the knife blades will lie on the same cutter-head radius even after having been re-ground, after each re-grinding operation a correspondingly thicker interchangeable flank plate **64** is attached to the surface of the knife shank, for instance by means of a dovetail joint.

The removal of the detritus may be effected by means of a number of conveyor worms, as shown in Figures 6 and 7. These worms are disposed on a suitably shaped scoop **40** with guide plates. They push the detritus on to a conveyor belt **42** situated in the rear.

Another form of detritus removal is shown in Figures 8 to 10. By means of suitably formed blades **92** a conveyor wheel **91** functioning in the manner of a multi-threaded worm pushes the bored-out material rearwards

and upwards against the stationary plate disc **95** until the material can slip through the opening **94** in this disc **95** on to the conveyor belt 42. The conveyor wheel **91** may be attached to the rotary member itself or it may rotate as an independent wheel at a greater speed than the said member. Intermediate blades **96** effect more complete filling of the conveyor cells.

For baking or damp material there is provided a spring-loaded swinging scraper **88** which is pivoted about the shaft **97** and which during the rotation of the conveyor wheel automatically pulls on to the conveyor belt **42** at least part of the material adhering to the conveyor blades.

In order to prevent the machine from being overloaded in consequence of violent load fluctuations which cannot be observed by the operator, and also to achieve the greatest possible advance or feed for a given cutting speed, according to the invention a fully automatic regulating device is proposed, which is diagrammatically illustrated in Figure 19.

Driving of the rotary plate is effected through the toothed rim **17** and the worm units **19** from a transmission means **35** if desired, through a coupling contained in the means **35** from which means the track mechanism **6** also is driven in this instance. Between this transmission **35** and the driving motor **22** there is a continually variable drive **24** which can be adjusted by oil-hydraulic means by means of the oil-pressure servomotor **36**, depending on the load on the worms **25**, i. e. on the additional or assisting torque.

The brake-knife holders **12** are formed as pistons sliding, with no leakage, in cylinderrs **136** attached to the rotary plate **5** and drawn back out of engagement by springs **37**. The distributor **38** is provided with a main piston **39** to which liquid is admitted from the automatic regulating device, and with a separate oil pressure piston **45** for each brake knife. This arrangement according to the invention positively ensures uniformly in the positions of all the brake knives and therefore prevents individual knives from jumping out into hollow spaces which may be present in the rock.

The automatic device **46** consists essentially of the piston valve **47**, the relay magnet switch **48** and the piston valve **49**. The regulating pressure oil is stored in a pressure container **50** provided with an air-cushion, this container being automatically charged by the pump **51** through the pressure regulating switch **52**. The container **53** contains the returning pressureless oil. The relay **48** is actuated electrically, or alternatively hydraulically or mechanically, by means of the electric torque switches installed at the cutter head drive mechanisms.

The manner of operation of this apparatus is as follows. The regulating transmission **24** is adjusted for minimum advance or feed, whereby the machine moves slowly towards the material to be bored, for instance rock. As soon as the cutting knives have engaged, the cock **54** is opened and the pressure oil flows out of the container **50** through the piston valve **47**, in the direction of the arrows in the drawing, through the servomotor **36** and adjusts the drive transmission to a greater feed speed. This causes increased depth of cut and power consumption, and therefore also increased torque. This increases the pressure on the worms and consequently causes the oil pressure in the cylinders **29** to rise. If the permissible assisting or additional torque is exceeded, the oil pressure acting through the duct **55** causes the piston valve **49** to be lifted against the adjustable spring **56**. The consequence thereof is that pressure oil flows into the distributor **38** and thereby brings the brake knives **12** into action. When as a result of the braking action so produced the pressure in the worm cylinder decreases again to the permissible value, the brake piston moves back again under the pressure of the spring **56**. It allows pressure oil to flow away into the container **53**, the brake knives **12** being withdrawn again by their back-pressure and the action of the springs **37**.

If the oil pressure in the cylinders **29** rises still further by reason of a very great additional or assisting torque which is too great to be taken by the brake knives, then the piston valve **47** also is raised against the adjustable spring **68**. This causes reversal of the flow of oil through the servomotor **36**, and therefore of the direction of rotation thereof. This reduces the depth of cut of the cutting knives and therefore reduces the additional or assisting torque. This goes on until such time as the pressure in the cylinders **29** has fallen below the pressure of the springs **68** again.

If the torque on the cutter head rises above the permissible value for instance as a result of localised occlusion of hard rock, breakage of a knife or the like, the switch **66** closes an auxiliary circuit **67** which by means of a solenoid **48** displaces the piston valve **47**. This causes the cutting depth to be reduced, as described above, until the overloading of the machine ceases. In addition this auxiliary circuit may also be actuated by a maximum-current device of the main motor **9**, so that protection of the motor can be achieved as a result.

Protracted oscillation of the two piston valves **47** and **49** can be prevented by employing springs **56** and **68** having stepped or staged characteristics.

In this document the term "galleries" means not only normal galleries but also tunnels and in general hollow spaces in rock, coal, salt, and minerals of all kinds, and other parts of the earth's crust having a length or depth exceeding their height or width. It includes vertical or inclined shafts, pressure galleries or the like.

It will be understood from the above that the present invention is not limited to the elements, members, steps and arrangements specifically described above and reinstated in the drawings and can be carried out with various modifications without departing from the scope of the invention, as defined in the appended claims.

What is claimed is:

1. A tunnelling machine comprising a frame shaft, a plate rotatable about the shaft, cutter heads rotatably mounted on the plate and having axes each including an acute angle with the axis of the frame shaft, knives on the periphery of each cutter head projecting substantially radially thereof and having cutting edges each coplanar with the rotation axis of the respective cutter head, means driving the plate, other means rotating the cutter heads, third means propelling the machine forward whereby the knives are imparted a planetary movement along a helical path about the frame shaft during propulsion of the machine.

2. The machine according to claim 1 and wherein the cutting edges each decline rearwardly toward the axis of the respective cutter head.

3. The machine according to claim 1 and wherein the cutter head has grooves and each knife includes a shank of a trapezoidal cross section and tapering toward its free end and received in a groove and also comprising an interchangeable flank plate for clamping the shank of a knife in a groove.

4. The machine according to claim 1 and wherein the cutter head has an internally toothed ring, at least two planetary pinions meshing with the ring, bushes supporting the planetary pinions, laminated plate springs mounted in the cutter head and yielding in a tangential direction only for supporting the bushes, and an internal pinion meshing with the planetary pinions, and journaled in the cutter head.

5. The machine according to claim 4 and wherein said bushes bear against the springs by surfaces somewhat rounded.

6. The machine according to claim 1 and wherein the inclination of the non-cutting surfaces of the cutter heads to the frame tube axis of the machine exceeds the pitch angle of the knife path.

7. The machine according to claim 1 and also comprising transmission means including coupling means oper-

able to connect the means driving the plate to the third means propelling the machine forward.

8. The combination according to claim 1 and wherein the cutting edge of each knife is parallel to the rotary axis of the respective cutter head.

9. The combination according to claim 1 and also comprising a continuously variable transmission mechanism driving the third means propelling the machine forward, and wherein the means driving the plate comprises at least one worm gear driven by the transmission mechanism, a toothed rim on the plate driven by the worm wheel of the worm gear, hydraulic means braking the plate in response to a predetermined liquid pressure and connected to the worm of the worm gear, the load on the worm generating the predetermined pressure, and means assuring equal distribution of load among several worms.

10. The machine according to claim 9 and wherein the hydraulic means includes a servomotor for varying the ratio of the transmission mechanism, and a cylinder and piston slidable therein and connected to the worm and controlling by the liquid in the cylinder the operation of the servomotor to render same inoperative at a second predetermined pressure, higher than the first mentioned pressure.

11. The machine according to claim 10 and wherein the hydraulic means includes a hydraulic automatic regulating device including two piston valves, one of the piston valves controlling the hydraulic brake means and the other controlling the servomotor and also comprising electric circuits, one for each cutter head, switches, one for each circuit, and arranged on a cutter head driving means and normally open and closed by a predetermined resistance encountered by the knives, an electromagnet having a coil connected to the circuits and energized by the closing of the switches and including a plunger displacing the other piston valve to influence the servomotor varying the transmission mechanism.

12. The mechanism according to claim 1 and also comprising braking knives carried by the plate and movable beyond the periphery thereof against the tunnel being bored and hydraulic means responsive to a predetermined resistance encountered by the cutting knives and moving the braking knives against the tunnel to brake the plate.

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