July 4, 1967 J. BOESSNER 3,328,971

SHIELD TUNNELING PROCESS AND MACHINE FOR CONSTRUCTING A TUNNEL

Filed Oct. 22, 1964

3 Sheets-Sheet 1

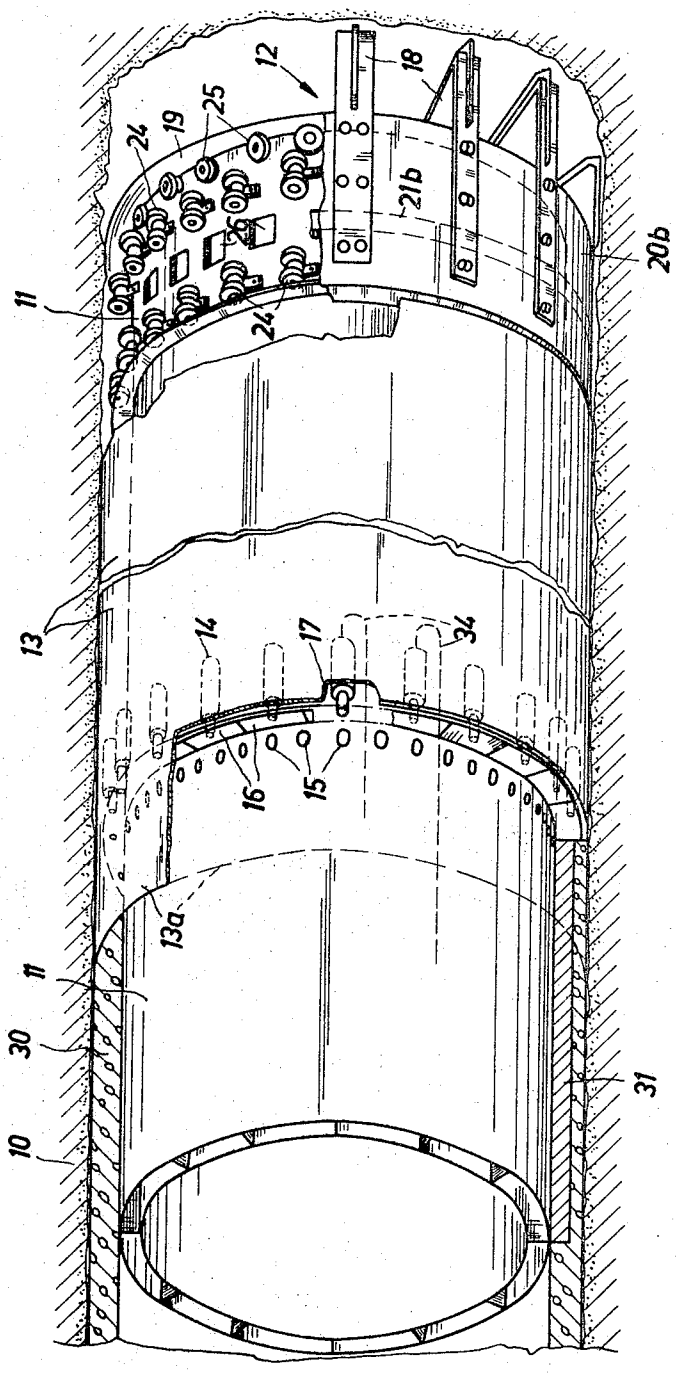


Fig. 1

Inventor:
JOSEF BOESSNER

By
OSTROLENK, FABER, GERB & SOFFEN
ATTORNEYS

July 4, 1967 J. BOESSNER 3,328,971

SHIELD TUNNELING PROCESS AND MACHINE FOR CONSTRUCTING A TUNNEL

Filed Oct. 22, 1964

3 Sheets-Sheet 2

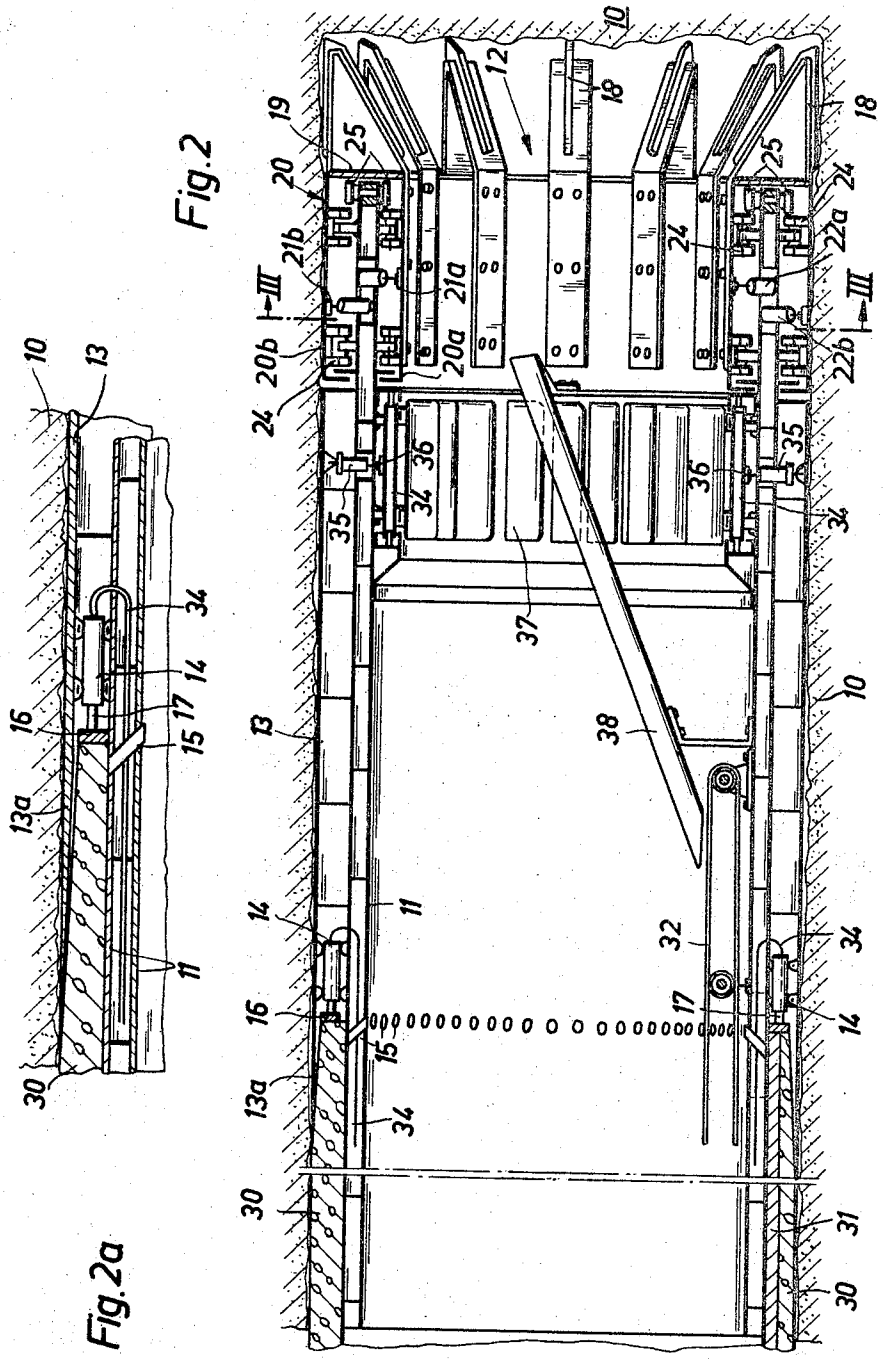


Fig. 2

Fig. 2a

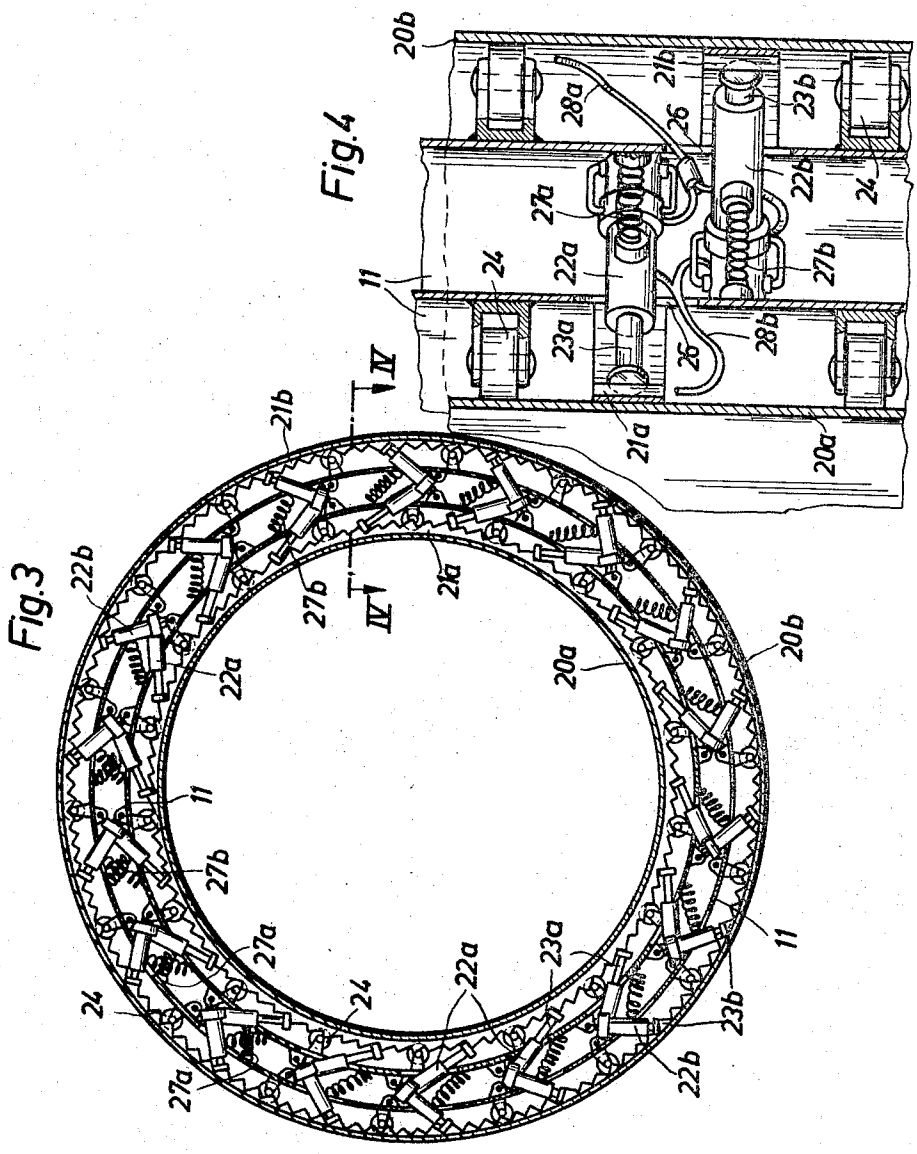
Inventor:
JOSEF BOESSNER
By
OSTBOLENK, FABER, GERB & SOFFEN
ATTORNEYS

July 4, 1967 J. BOESSNER 3,328,971

SHIELD TUNNELING PROCESS AND MACHINE FOR CONSTRUCTING A TUNNEL

Filed Oct. 22, 1964

3 Sheets-Sheet 3



Inventor:
JOSEF BOESSNER

By
OSTROLENK, FABER, GERB & SOFFEN
ATTORNEYS

United States Patent Office 3,328,971 Patented July 4, 1967

3,328,971

SHIELD TUNNELING PROCESS AND MACHINE FOR CONSTRUCTING A TUNNEL

Josef Boessner, 5 Ludwig-Thoma-Str., Bad Aibling, Upper Bavaria, Germany

Filed Oct. 22, 1964, Ser. No. 405,658
9 Claims. (Cl. 61—84)

This invention relates to a shield tunneling process for lining a tunnel having a circular cross-section with concrete by means of a combined tunnel milling and concreting machine, in which process the formwork is advanced in steps with the heading machine and the rearwardly directed reaction force occurring when the heading machine is being advanced is utilized for pressing. The invention relates further to a combined tunnel milling and concreting machine for the simultaneous milling and concreting of tunnels having a circular cross-section according to such shield tunneling process, in which machine a second guide tube is spaced around a base tube provided at its forward end with an annular milling cutter and this second guide tube is firmly connected to the base tube and is shorter than the latter approximately by one-half, the outside diameter of the guide tube being approximately as large as the diameter of the bore to be formed by the milling cutter and the outside diameter of the base tube determining the diameter of the concrete-lined tunnel, and in which machine hydraulic jacks are arranged in the space between the two tubes and act through openings formed in the base tube behind the guide tube to compress the introduced concrete by means of jack pistons and segments secured to them so that the concrete is compacted and a heading force is exerted, which acts on the annular milling cutter.

It is already known to bore tunnels with the aid of heading machines. In one known process the tunnel is lined behind the heading machine by assembling so-called tubbings. Tubbings are cylinder segments, which have in the longitudinal direction of the tunnel a size of, e.g., 1 meter. Whenever the heading machine has advanced by a predetermined increment, e.g., of 1 meter, the tunnel tube behind the heading machine is supplemented by a cylinder section assembled from the tubbings. During the boring operation, the heading machine is backed by that portion of the tunnel tube which is assembled from the tubbings. As numerous spaces remain between the resulting tunnel tube and the rock, the known process comprises forcing a concrete mixture into the spaces. The interior of the tunnel tube may also be lined with concrete.

It is also known to line tunnels with concrete directly, without using tubbings.

The known processes have the disadvantage of enabling only an intermittent, discontinuous operation because the advance must be interrupted while another section of the tunnel tube is being lined. To line the bore in the soil with concrete, it was previously necessary to erect a separate formwork. Such a formwork used in tunnel construction must meet very stringent requirements because the concrete must be filled in under high pressure.

Another process is known, in which the coarse aggregate of the concrete is first filled into a formwork which is connected to the milling apparatus. Then the milling apparatus begins to operate while being backed by the filled-in coarse aggregate and compressing the same. Liquid concrete is introduced only thereafter. This process is also discontinuous and is very time-consuming owing to the separate introduction of coarse aggregate and concrete. Besides, the concrete cannot be relied upon

to reach all interstices when the coarse aggregate has been compressed.

It is an object of the invention to provide a process and a machine of the kind mentioned first hereinbefore, with which a quasi-continuous operation is ensured and a wall is obtained which is uniformly lined with concrete placed under high pressure. Besides, the machine is required to comprise a milling cutter unit which is as compact as possible and yet very strong.

With this object in mind, the process according to the invention comprises injecting the liquid concrete under pressure simultaneously and at equal rates into a plurality of openings provided on the periphery of a cylinder immediately behind the jack pistons whenever the milling cutter unit backed by the previously introduced concrete has been adanced by an increment of about 5–30 mm. since the last injection of concrete and the jack pistons have been retracted by this increment, whereafter pressure is again admited to the jack cylinders to advance and force the milling cutter unit against the tunnel face while compressing the injected concrete.

The preferred heading machine is characterized according to the invention in that the milling tools are secured to a double cylinder surrounding the base tube and consisting of two cylinder sections, which are connected at the forward end by an annular web, said double cylinder being adapted to be driven to perform a rotary motion.

Further advantages and details of the invention will become apparent from the subsequent description of an illustrative embodiment with reference to the accompanying drawings, in which

FIG. 1 is a perspective view, partly broken away, which shows a heading machine according to the invention in operation,

FIG. 2 is a central vertical longitudinal sectional view of the heading machine according to the invention in operation,

FIG. 2*a* is an enlarged view showing a portion of FIG. 2,

FIG. 3 is a sectional view taken on line III—III of FIG. 2 and

FIG. 4 is a sectional view taken on line IV—IV of FIG. 3.

According to FIGS. 1 and 2, the heading machine according to the invention comprises a base tube **11**. The outside diameter of this tube **11** determines the inside diameter of the concrete-lined tunnel tube **30**. The base tube **11** is assembled, e.g., from separate steel tubbings. Alternatively, it may consist of two metal cylinders connected by transverse webs, as is shown in FIG. 1.

An annular milling cutter **12** is mounted at the forward end of the base tube **11**. In the illustrative embodiment which is described, this milling cutter comprises a double cylinder **20**, which is rotatable about its central axis and includes an outer cylinder section **20***b* and an inner cylinder section **20***a*, milling cutters **18** attached to this double cylinder. The two cylinder sections are firmly connected at their forward end by an annular web **19**. At the rear end, an annular opening left between the two cylinder sections receives the forward end of the base tube **11**, which carries the double cylinder and guides it during its rotation. The double cylinder is mounted on the base tube by means of rollers **24**, which are mounted at the inside and outside of the base tube **11** and engage the inside surfaces of the surrounding double cylinder and can roll on the same. The rollers **24** serve for radially locating the double cylinder **20**. Forwardly projecting rollers **25** are mounted on the forward edge of the base tube and serve for axially supporting the double cylinder **20** and for transmitting the heading force.

The milling cutter tools proper **18** are secured to the double cylinder **20** and project forwardly. The outer edge of the milling cutter tools **18** determines the wall of the milled bore. The inner edge of the milling cutter tools is preferably inwardly inclined.

The drive means for the annular milling cutter **12** is best apparent from FIGS. 3 and 4 in conjunction with FIGS. 1 and 2.

Ratchet rings **21***a* and **21***b* are secured to the inside surfaces of the cylinder sections **20***a* and **20***b*, respectively. According to FIG. 2, the two ratchet rings **21***a* and **21***b* are relatively offset. Opposite to the ratchet rings, hydraulic jacks **22***a* and **22***b* comprising jack pistons **23***a*, **23***b* are hinged to the base tube **11**. The ends of these pistons interfit with the teeth of the ratchet rings. The jacks are prestressed by springs **27***a* and **27***b*, respectively, so that the jack pistons **23***a* and **23***b* engage the ratchet rings **21***a* and **21***b*, respectively. All springs **27***b* are shown in FIG. 3 but only some of the springs **27***a*, for the sake of clearness.

The hydraulic jacks are double-acting and by connection to a suitable, controllable source of pressure fluid may be operated in one direction or the other. When the jack pistons **23***a* and **23***b* are being extended, a rotation is being imparted to the double cylinder **20** and to the milling cutter tools **18** relative to the base tube **11**.

In a preferred embodiment, successive pairs of jacks are connected to the source of pressure fluid and controlled so that when one group of jack piston pairs are being extended the remaining pairs of jack pistons are being retracted while slipping over the teeth of the ratchet rings. In this way, a continuous rotary movement may be obtained when one half of the pairs of jack pistons are being extended and the other half are being retracted. This mode of operation is illustrated in FIG. 4, in which the left-hand jack piston **23***a* is shown in an extended position and the right-hand one **23***b* in a retracted position.

The springs **27***a*, **27***b* act to maintain the ends of the jack pistons **23***a*, **23***b* continuously in engagement with the ratchet rings.

FIG. 4 shows also the two pressure fluid conduits **28***a*, **28***b*, which cause the extending and retracting movements of the jack pistons. As the annular milling cutter is hydraulically driven, large forces can be transmitted, such as are required for breaking out rock. The arrangement which has been described has the further advantage of being very compact. In known heading machines, the entire cross-section of the machine is occupied by driving means, such as motors and the like.

In order to increase the space required for mounting the hydraulic jacks **22**, openings **26** are formed according to the drawing in the outside and inside walls of the preferably double-walled base tube **11**.

The jacks **22***a* acting on the inside ratchet ring **21***a* extend through openings **26** to the outside wall of the base tube **11** and are hinged there. The jacks **22***b* co-operating with the outer ratchet ring **21***b* extend also through openings **26** to the inside wall of the base tube **11**.

A guide tube **13** is firmly connected to the base tube **11** and is seated on the same immediately behind the annular milling cutter **12**. This guide tube is much shorter than the base tube and its length is preferably one half the length of the base tube **11**. The outside diameter of the guide tube **13** is substantially as large as the diameter of the milled tunnel bore. The tube **13** serves for guiding the heading machine within the tunnel bore.

Further hydraulic jacks **14** are disposed between the rear portion of the guide tube **13** and the base tube **11** and are supplied with pressure through conduits **34**. The jack pistons **17** of these jacks extend rearwardly from the guide tube **13**. Ring segments **16** are secured to the ends of the jack pistons **17** and contact each other and combine to form a ring surrounding the base tube **11**. Numerous openings **15** for introducing the concrete are provided on a circumference of the base tube **11** behind the ring segments **16**.

A keel plate **31** is secured to the bottom of the base tube **11** behind the guide tube **13** and serves to transmit the reaction torque, which occurs during the operation of the annular milling cutter **12**, to the concrete and through the same to the rock **10**. It will be understood that the keel plate **31** may be mounted at any other point of the base tube **11**. This plate leaves in the concrete a groove, which may either be subsequently closed or may be used to accommodate conduits or for discharging liquids.

According to FIGS. 2 and 2*a*, the outer cylinder of the base tube **11** is rearwardly extended by a tapering slide plate **13***a* to provide a completely tight annular space for the injection of the concrete.

For the discharge of the material which has been removed, a drum **34** which is rotatable about the longitudinal axis of the arrangement may be disposed closely behind the annular milling cutter **12** and supported by rollers on the base tube **11**. A plurality of troughlike containers **37** are secured to the inside of the drum **34** and during the rotation of the drum receive the removed material when they are in the lowest position. In the highest position of the troughs **37**, the material falls out of them onto a chute **38**, which delivers the material to a conveyor belt or the like.

The rotation of the drum **34** is effected by means similar to the means for driving the double cylinder **20**. A ratchet ring **36** is secured to the outside of the drum **34** and cooperates with the jack pistons of hydraulic jacks **35**, which are hinged to the guide tube **13** and extend through openings in the base tube **11**. By springs, not shown, the hydraulic jacks are caused to engage the ratchet ring.

The heading machine according to the invention operates as follows:

When the jack pistons **17** have been retracted, liquid concrete is injected through the openings **15** into the annular space between the base tube **11** and the rock **10** and adheres to the previously compressed concrete **30**. Pressure is then admitted to the hydraulic jacks **14** so that a heading force is transmitted to the rotating annular milling cutting **12** and the reaction force causes the injected concrete to be compressed. After an advance of 5–30 mm., the jack pistons **17** are retracted to this extent and then further concrete is injected. Thereafter, pressure is again admitted to the jacks **14**. As the time required for retracting of the piston **17** and for injecting the concrete into the relatively small annular space is relatively short, the apparatus operates quasi-continuously.

The material which has been broken out or, in the case of sand, scooped out by the milling cutter tools **18**, drops into the troughlike containers **37** and passes over the chute **38** onto a conveyor belt **32**. The concrete may be supplied to the point of operation by suitable vehicles.

The jacks **14** disposed within a quadrant are preferably connected to a separate, controllable source of pressure fluid so that four groups of separately controllable jacks are provided. When different pressures are applied to the different groups of jacks, a curve in a horizontal, vertical or inclined plane may be milled. The radius of curvature of a curve to be milled must obviously have a certain minimum value. In numerous cases, e.g., in the construction of underground railways, the minimum radius of curvature which can be achieved is sufficient for all requirements.

The heading machine according to the invention enables a simultaneous milling and concreting of tunnels, and the reaction force necessarily occurring during the advance of the milling cutter is advantageously utilized for compressing the back-filling concrete. The driving arrangement according to the invention is compact and yet provides for a considerable torque.

It may be pointed out that is cases in which the pressure supplied by the concrete pump is not sufficient, the

arrangement may be such that the inlet openings **15** may be closed while the concrete is being compressed by the jackets **14**. This closing may be effected by the jack pistons **17** or the segments **16** themselves, if they are provided, e.g., with an additional flange, which closes the openings **15** when the pistons **17** are being extended.

The slide plate **13***a* has such a length that the concrete **30** at the rear edge of the slide plate is still workable during the operation of the machine so that it can be snugly applied to the wall of the bore.

What is claimed is:

1. A shield tunneling machine for milling and concreting a tunnel having a circular cross-section in a succession of cycles of operation, said machine comprising a base tube having a forward end, an annular milling cutter carried by said base tube at said forward end, a guide tube spaced around said base tube and firmly connected thereto, the length of said guide tube being approximately one half the length of said base tube, said annular milling cutter being operable to form a bore having a diameter equal to the outside diameter of said guide tube, said base tube and guide tube defining between them a first annular space, a plurality of circumferentially spaced, axially extending hydraulic jacks disposed in said first annular space and connected to said base tube, said base tube extending behind said guide tube to define with said bore a second annular space, said base tube being formed behind said guide tube with peripherally spaced openings communicating with said second annular space, means for introducing concrete through said openings into said second annular space, said jacks comprising jack pistons having ring segments secured thereto, said jacks being operable to force said ring segments against concrete previously introduced into said second annular space and to advance said annular milling cutter, a rotatably mounted double cylinder surrounding said base tube and comprising two cylinder sections having a forward end, and an annular web connecting said cylinder sections at said forward end, and means for rotating said double cylinder, said milling cutter comprising milling cutter tools carried by said double cylinder.

2. A machine as set forth in claim **1**, in which said double cylinder comprises an inner cylinder section having on its outside a ratchet ring, and an outer cylinder section having on its inside a ratchet ring, a plurality of substantially tangentially extending, double-acting jacks hinged to said base tube and comprising double-acting jack pistons, springs being arranged to urge said double-acting jack pistons into engagement with said ratchet rings, said ratchet rings being shaped to impart rotation to said double cylinder and milling cutter tools in response to an extending movement of said double-acting jack pistons, and to permit said double-acting jack pistons to slip over said rings during a retracting movement of said double-acting jack pistons.

3. A machine as set forth in claim **2**, in which said ratchet rings are axially spaced.

4. A machine as set forth in claim **2**, in which said double-acting jackets comprise two equal-numbered sets and the jacks of each set are arranged to be extended and retracted in unison and in phase opposition to the jacks of the other set, each jack of each set being disposed between two jacks of the other set, so that the operation of said jacks results in a continuous rotation of said annular milling cutter.

5. A machine as set forth in claim **2**, in which said base tube comprises two walls and is formed adjacent to said ratchet rings with openings and each of said double-acting jacks is hinged to one of said walls of said base tube and extends through one of said openings in the other wall of said base tube.

6. A machine as set forth in claim **1**, which comprises rollers engaging the forward end portion of said base tube on the inside and outside and supporting said double cylinder.

7. A machine as set forth in claim **3**, in which said axially extending jacks are operable to exert pressure to said base tube and which comprises rollers for transmitting said pressure from said base tube to said double cylinder.

8. A machine as set forth in claim **1**, which comprises rigid keel plates mounted on the outside of said base tube behind said guide tube and extending in the direction of movement of the machine, said keel plates being arranged to transmit the reaction torque which is due to the operation of said annular milling cutter to the compressed concrete in said second annular space.

9. A machine as set forth in claim **1**, which comprises a drum rotatably mounted on said base tube behind said milling cutter, means for driving said drum, said means comprising hydraulic jacks and a ratchet ring, troughlike containers mounted on said drum and adapted to receive material detached by said milling cutter, a chute for receiving said detached material, and a belt conveyor for receiving said detached material from said chute.

References Cited

UNITED STATES PATENTS

1,351,137	8/1920	Sheen	61—84
3,075,591	1/1963	Pirrie et al.	61—85 X

FOREIGN PATENTS

443,158	2/1936	Great Britain.
710,494	6/1954	Great Britain.
970,016	9/1964	Great Britain.

DAVID J. WILLIAMOWSKY, *Primary Examiner.*

JACOB SHAPIRO, *Examiner.*