

Tunnelling machine

The invention relates to a tunnelling machine having
5 the features of the preamble of claim 1.

Such a tunnelling machine is known from DE 20 2020 104
813 U1. This previously known tunnelling machine has a
drive shaft that is designed to rotate a cutting
10 wheel. Furthermore, there is a sealing arrangement
which is designed to seal an annular gap formed
between stationary components and rotating components
around the drive shaft. The sealing arrangement has a
number of sealing rings and chamber rings arranged
15 between the sealing rings. Furthermore, there is a
fluid-supply assembly designed to supply lubricants
and a number of receiving chambers formed between
adjacent sealing rings, which comprise a first
internal chamber located at the front in the direction
20 of advance and a second internal chamber located at
the rear of the first internal chamber in the
direction of advance, which can be supplied with
lubricants.

25 EP 3 854 990 A1 discloses a cascade-type sealing
arrangement similar to that disclosed in the
aforementioned DE 20 2020 104 813 U1, in which a
pressure increase is provided in the interior area
relative to a support pressure.

30 CN 107 401 678 A also discloses a cascade-type sealing
arrangement for a tunnelling machine similar to that
disclosed in the aforementioned DE 20 2020 104 813 U1,
which is designed for high support pressures and in
35 which a pressure equalization chamber is provided.

DE 10 2009 014 214 A1 discloses a sealing device for a rotary feedthrough for sealing a vacuum against atmospheric pressure, which has an intermediate chamber with an intermediate vacuum.

The invention is based on the object of specifying a tunnelling machine of the type mentioned at the outset, which is characterized by a resource-saving sealing arrangement with relatively low wear and which, for environmental protection reasons, also leaves the conditioning of media in the direction of advance in the area in front of the sealing arrangement essentially unaffected during normal operation.

This object is solved in a tunnelling machine of the type mentioned at the outset according to the invention with the characterizing features of claim 1.

Due to the fact that, in a tunnelling machine according to the invention, there is an intermediate pressure in the area of the first internal chamber which lies between the pressure in the area in front of the first internal chamber in the direction of advance and the pressure in the second internal chamber, the lubricant present in the first internal chamber remains substantially loss-free in the first internal chamber, so that, during normal operation, lubrication is largely resource-friendly and environmentally-friendly and there is no leakage of lubricant from the first internal chamber into the area in the direction of advance in front of the first internal chamber, which is usually conditioned with additives of a different material class and is

necessary for operation in conventional tunnelling machines, thereby improving environmental protection.

5 Further useful designs are the subject matter of the dependent claims.

Further useful designs and advantages of the invention are apparent from the following description of an exemplary embodiment of the invention with reference
10 to the figures of the drawing.

The drawings show as follows:

15 Fig. 1 shows, in a perspective view, an exemplary embodiment of a tunnelling machine according to the invention in the front area on the excavation side, with a view of a cutting wheel,

20 Fig. 2 shows, in a perspective view corresponding to Fig. 1, the exemplary embodiment of the tunnelling machine with the cutting wheel removed and a view of a rotary drive arrangement of the tunnelling machine, which
25 is sealed by an exemplary sealing arrangement comprising a first sealing area arranged radially on the outside and a second sealing area arranged radially on the inside,

30 Fig. 3 shows a sectional view of an exemplary embodiment of the first sealing area of the sealing arrangement according to Fig. 2 for the rotary drive arrangement,

Fig. 4 shows a sectional front view of a section of the sealing areas of the sealing arrangement according to Fig. 2,

5 Fig. 5 shows a perspective view of a section of a chamber ring of the sealing arrangement according to Fig. 3,

10 Fig. 6 shows, in a perspective view enlarged relative to the representation according to Fig. 5, a partial section of a chamber ring on both sides of a groove boundary,

15 Fig. 7 shows, in a sectional view, an exemplary embodiment of the second sealing area of the sealing arrangement according to Fig. 2,

20 Fig. 8 shows, in a schematic hydraulic circuit diagram, an embodiment of a fluid-supply assembly,

25 Fig. 9 shows, in a schematic view, an exemplary sealing arrangement with an exemplary first pressure curve,

Fig. 10 shows, in a schematic view, the exemplary sealing arrangement according to Fig. 9 with an exemplary second pressure curve, and

30 Fig. 11 shows, in a schematic view, the exemplary sealing arrangement according to Fig. 9 with an exemplary third pressure curve.

35 Fig. 1 shows, in a perspective view, an exemplary embodiment of a tunnelling machine set up for driving

a tunnel in the area of a boring head 103. The boring head 103 is designed with a shield shell 106 closed in the circumferential direction and with a cutting wheel 109, which, in a direction of advance, closes off the shield shell 106 at the front end to form a working face with a mining area 112 and is facing the viewer in the illustration according to Fig. 1. The cutting wheel 109 is equipped with a number of excavation tools, which are not described in detail, in a manner that is customary per se, and is rotatable.

Fig. 2 shows, in a perspective view corresponding to the view according to Fig. 1, the boring head 103 with a view of a baffle 203 located behind the cutting wheel 109, which is not shown in Fig. 2, in the direction of advance. Fig. 2 shows that the baffle 203 has a ring-segment-like basic shape with a radially inner breakthrough area in which a drive shaft 206 designed as a hollow shaft is arranged. During operation of the tunnelling machine, the drive shaft 206 is in fixed rotational engagement with the cutting wheel 109, which is not shown in Fig. 2, and with a rotary drive arrangement 209 arranged behind the baffle 203 in the direction of advance, which is designed to drive the cutting wheel 109 to rotate in two directions as appropriate.

To seal the drive shaft 206 in the area where it passes through the baffle 203, the exemplary embodiment described has a sealing arrangement 212, which has a first sealing area 215 arranged on the radially outer side and a second sealing area 218 arranged on the radially inner side.

Fig. 3 shows a sectional view in a sectional plane extending in the axial direction of the first sealing area 215 of the sealing arrangement 212 according to Fig. 2.

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The sealing arrangement 212 has a head seal 303 in the first sealing area 215, which is arranged at the front in the direction of advance and delimits a head chamber 306, which is suitably designed in a labyrinth-like manner and extends in the direction of the cutting wheel 109 and thus into the mining area 112. The head chamber 306 is bounded radially on the inside by a sealing support ring 309 and on the front side by an end ring 312. The head seal 303, in turn, is arranged between the sealing support ring 309 and a cover ring 315. The head chamber 306 is in fluid mechanical connection with a feed line 321 of a feed line arrangement 324 via end sections 318 formed in the end ring 312 and in the cover ring 315. A conditioning agent can be fed in via the feed line 321 opening into the head chamber 306, which is designed to condition the area in the direction of advance in front of the sealing arrangement 212. The head seal 303 is held on the front side in the direction of advance by a fixing section 327 of the end ring 312.

A first chamber ring 330 is arranged on the rear side of the head seal 303 in the direction of advance, which is arranged as a stationary component between the sealing support ring 309 and a seal carrier 336 arranged radially outside the sealing support ring 309, forming an annular gap 333.

A first internal seal 339 is arranged on the rear side of the first chamber ring 330 in the direction of

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advance, which is held by the first chamber ring 330 on its front side in the direction of advance and by a second chamber ring 342 on its rear side in the direction of advance. The second chamber ring 342 is also located between the sealing support ring 309 and the seal carrier 336.

A second internal seal 345 is positioned on the rear side of the second chamber ring 342 in the direction of advance, next to which a third chamber ring 348 is arranged on its rear side in the direction of advance.

Finally, in the exemplary embodiment shown in Fig. 3, an end seal 351 is arranged on the rear side of the third chamber ring 348 in the direction of advance, which is held on the rear side in the direction of advance by a fixing section 354 resting against the seal carrier 336.

As can be seen from the illustration in Fig. 3, the head seal 303, the internal seals 339, 345, and the end seal 351 are each formed with a block-like base body 357, which is positioned radially on the outside, and with a sealing lip 360, which is pivotably attached to the respective base body 357 via a joint section with a relatively low material thickness and rests on the sealing support ring 309 with a certain pretension. The sealing lips 360 of the head seal 303 and the internal seals 339, 345 are aligned so that they point in the direction of the end ring 312, while the sealing lip 360 of the end seal 351 is aligned pointing away from the end ring 312 and toward the fixing section 354.

Furthermore, it can be seen from the illustration in Fig. 3 that the chamber rings 330, 342, 348 are each formed with a radially outwardly located annular groove 363, which is open in the direction of the seal carrier 336 and into which the end sections 318 of feed lines 321 of the feed line arrangement 324 open for the supply of lubricants or compressed air as required. The annular grooves 363, in turn, open into passage recesses 366 distributed in the circumferential direction, which create a fluid connection between the annular grooves 363 and the annular gap 333.

Thus, a first internal chamber 369 is formed as a receiving chamber between the head seal 303 and the first internal seal 339, and a second internal chamber 372 is formed between the first internal seal 339 and the second internal seal 345, while an end chamber 375 is formed as a further receiving chamber between the second internal seal 345 and the end seal 351.

During mining operation, the pressure in the head chamber 306, which is connected to the mining area 112, is at least slightly higher than the support pressure prevailing in the mining area 112, wherein the support pressure in pressure-supported mining operation corresponds to a multiple of atmospheric pressure.

The area on the side of the end seal 351 opposite the end chamber 375 is normally bounded by a roller rotary joint 378 via a connecting line 381, which extends in sections between the sealing support ring 309 and the roller rotary joint 378, on its rear side in the

direction of advance, with a pressure prevailing in a gear housing, for example atmospheric pressure.

Furthermore, it can be seen from the illustration in Fig. 3 that a flange ring 384 is arranged radially on the inside of the sealing support ring 309, which is connected in a rotationally fixed manner to the drive shaft 206 not shown in Fig. 3. A labyrinth plate 387 is detachably attached to the end ring 312 on its front side in the direction of advance by means of a screw connection.

In the first sealing area 215, the sealing support ring 309, an inner ring of the roller rotary joint 378 and the flange ring 384 are moving components, while the head seal 303, the end ring 312, the cover ring 315, the first chamber ring 330, the seal carrier 336, the first internal seal 339, the second chamber ring 342, the second internal seal 345, the third chamber ring 348, the end seal 351, an outer ring of the roller rotary joint 378, and the labyrinth plate 387 are stationary components.

It is understood that in variations of the exemplary embodiment described above, particularly in the case of tunneling with very high support pressures, at least one additional internal chamber is provided beyond the two aforementioned internal chambers 368, 372 in order to achieve pressure reduction in at least three or more internal chambers, including the provision of redundancy.

Fig. 4 shows a sectional view in the area of the first internal chamber 369, showing a detail of the sealing arrangement 212 in the first sealing area 215. The

illustration in Fig. 4 shows that the passage recesses 366 are arranged at regular intervals around the circumference of the first chamber ring 330. In the apex area shown in Fig. 4, which is located at the top in relation to gravity, at its zenith a zenith groove boundary 403 is arranged and an edge groove boundary 406 is arranged on both sides of the zenith groove boundary 403, which limit the annular groove 363 in the circumferential direction as a flow brake and, for practical purposes, also seal it to a certain degree against the seal carrier 336. This ensures that, in both directions of rotation of the cutting wheel 109, lubricant entering via the end sections 318 of the feed lines 321 is retained in the apex area and passes substantially completely through the passage recesses 366 to produce reliable lubrication in the apex area.

The areas around the second chamber ring 342, which is not visible in Fig. 4, and around the third chamber ring 348, which is also not visible in Fig. 4, are constructed accordingly.

Fig. 5 shows a sectional perspective view of the structure of the first chamber ring 330, wherein the second chamber ring 342 and the third chamber ring 348 are constructed accordingly. The representation according to Fig. 5 shows that a number of passage recesses 366 are formed between the zenith groove boundary 403 and each edge groove boundary 406. On the side of each edge groove boundary 406 facing away from the zenith groove boundary 403, further passage recesses 366 are formed in the first chamber ring 330 in order to ensure a supply of lubricants even outside the zenith area shown in Fig. 5.

Fig. 6 shows an enlarged perspective view corresponding to Fig. 5 of the area around a groove boundary acting as a flow brake, for example the zenith groove boundary 403. The illustration in Fig. 6 shows that the zenith groove boundary 403, like the edge groove boundaries 406, is formed by a groove stone 603 which crosses the annular groove 363 and terminates radially on the outside with the annular groove 363 and is detachably connected to the first chamber ring 330 by means of a groove stone fastening screw 606.

In a variation not shown, the zenith groove boundary 403 and the edge groove boundaries 406 are formed by cross pieces integrally formed with the respective chamber rings 330, 342, 348.

Fig. 7 shows a sectional view corresponding to the representation in Fig. 3 of the sealing arrangement 212 in the second sealing area 218. The illustration in Fig. 7 shows that the sealing arrangement 212 in the second sealing area 218 is constructed in its essential components in accordance with the first sealing area 215 explained above, wherein, in order to avoid repetitions, the two sealing areas 215, 218 are assigned the same reference signs and, in order to avoid repetition, are not explained in detail again below. One difference between the chamber rings 330, 342, 348 installed in the first sealing area 215 and the chamber rings 330, 342, 348 installed in the second sealing area 218 is usually that the chamber rings 330, 342, 348 installed in the second sealing area 218 are free of passage recesses 366 and are therefore solid and uninterrupted in the circumferential direction in the center area.

Furthermore, in the second sealing area 218, the sealing support ring 309 is designed as a stationary component, while the flange ring 384 is a rotating component.

The supply of lubricants for the internal chambers 369, 372 is provided via end sections 318 of feed lines 321 of the feed line arrangement 324 formed in the sealing support ring 309, which also extend, for example, through a gear housing 703 arranged radially on the inside of the sealing support ring 309. Separators 706 are arranged as flow brakes in the area of the end sections 318 of the feed lines 321. This ensures a reliable supply of lubricants in the apex area of the second sealing area 218.

In the second sealing area 218, the head seal 303, the end ring 312, the first chamber ring 330, the first internal seal 339, the second chamber ring 342, the second internal seal 345, the third chamber ring 348, the end seal 351, an inner ring of the roller rotary joint 378 and the flange ring 384 are moving components, while the sealing support ring 309, an outer ring of the roller rotary joint 378, and the gear housing 703 are stationary components.

Fig. 8 shows a schematic diagram of a fluid-supply assembly 803, which is specifically designed to feed lubricant or compressed air into the first internal chambers 369 and into the second internal chambers 372, as explained in more detail below, wherein the following explanations refer to the conditions at one of the sealing areas 215, 218, which behave in the same way for both sealing areas 215, 218.

The fluid-supply assembly 803 has a first level compensation container 806, which is connected to the zenith area of the first internal chamber 369 via a fluid inlet line 809 and to the first internal chamber 369 on the sump side via a fluid outlet line 812. For practical purposes, the fill level of the first level compensation container 806 is equipped with two fill level sensors, which are not shown in Fig. 8 for the sake of clarity, which are designed to emit a warning signal when a maximum fill level is exceeded or a minimum fill level is not reached in the first level compensation container 806. Furthermore, the fluid-supply assembly 803 has a circulation pump 815 which is connected via a closed circulation line 818 on the inlet side to the sump area of the first internal chamber 369 and on the outlet side to the zenith area of the first internal chamber 369. The circulation pump 815, which interacts with the first internal chamber 369, is designed to circulate lubricant fed into the first internal chamber 369 in order to ensure reliable lubrication in the zenith area, particularly in the case of large diameters, regardless of the respective pressure conditions in the internal chambers 369, 372 and in the end chamber 375, both in the first sealing area 215 and in the second sealing area 218.

Furthermore, the fluid-supply assembly 803 is equipped with a compressed air reservoir 821, which is designed to maintain a predetermined pressure and is connected to the first level compensation container 806 via a pneumatic throttle 824.1 and a switchable seat valve 827.1. Thus, when the seat valve 827.1 connected to it is in the open position, the first level compensation

container 806 can be pressurized with pressure originating from the first compressed air reservoir 821, specifically a pressure higher than atmospheric pressure as overpressure, so that the first internal chamber 369 can be pressurized with either lubricant or compressed air via the fluid inlet line 809.

Furthermore, a vacuum line 830 is connected to the first level compensation container 806 via a further throttle 824.2 and via a further switchable seat valve 827.2, which is connected to the inlet side of a vacuum pump 833 of the fluid-supply assembly 803. As explained in more detail below, the vacuum pump 833 is designed to apply a predetermined pressure lower than atmospheric pressure as a vacuum to the first internal chamber 369 relative to atmospheric pressure when the seat valve 827.2 arranged in the vacuum line 830 is in the open position and when the seat valve 827.1 arranged between the first compressed air reservoir 821 and the first level compensation container 806 is in the closed position.

Furthermore, it can be seen from the illustration in Fig. 8 that the first level compensation container 806 is connected to a pressure measuring unit 842 via a pressure measuring line 836 with an intermediate ball valve 839. The pressure measuring unit 842, which can be connected to the first level compensation container 806, is designed to measure the pressure prevailing in the first level compensation container 806 when required.

The fluid-supply assembly 803 also has a second level compensation container 845, which is connected to the zenith area of the second internal chamber 372 via a

fluid inlet line 809 and to the second internal chamber 372 on the sump side via a fluid outlet line 812. For practical purposes, the fill level of the second level compensation container 845 is equipped with two fill level sensors, which are not shown in Fig. 8 for the sake of clarity, which are designed to emit a warning signal when a maximum fill level is exceeded or a minimum fill level is not reached in the second level compensation container 845. Furthermore, the fluid-supply assembly 803 has a circulation pump 815 which is connected via a closed circulation line 818 on the inlet side to the sump area of the second internal chamber 372 and on the outlet side to the zenith area of the second internal chamber 372. The circulation pump 815, which interacts with the second internal chamber 372, is designed to circulate lubricant fed into the second internal chamber 372 in order to ensure reliable lubrication in the zenith area, especially in the case of large diameters.

The compressed air reservoir 821 of the fluid-supply assembly 803 is connected to the second level compensation container 845 via a pneumatic throttle 824.1 and a switchable seat valve 827.1. Thus, when the seat valve 827.1 connected to it is in the open position, the second level compensation container 845 can be pressurized with pressure originating from the compressed air reservoir 821, namely a pressure higher than atmospheric pressure as overpressure, so that the second internal chamber 372 can be pressurized with either lubricant or compressed air via the fluid inlet line 809.

Furthermore, the vacuum line 830, which is connected to the inlet side of the vacuum pump 833, is connected

to the second level compensation container 845 via a further throttle 824.2 and a further switchable seat valve 827.2. As explained in more detail below, the vacuum pump 833 is designed to apply a predetermined vacuum to the second internal chamber 372 relative to atmospheric pressure when the switchable seat valve 827.2 located in the vacuum line 830 is open and when the seat valve 827.1 located between the compressed air reservoir 821 and the second level compensation container 845 is closed.

Furthermore, it can be seen from the illustration in Fig. 8 that the second level compensation container 845 is connected to a pressure measuring unit 842 via a pressure measuring line 836 with an intermediate ball valve 839. The pressure measuring unit 842, which can be connected to the second level compensation container 845, is designed to measure the pressure prevailing in the second level compensation container 845 as required.

In addition to the arrangement in connection with the first internal chamber 369 and the first level compensation container 806, a ventilation part 848 is connected to the second level compensation container 845 via a pneumatic throttle 824.3 and a switchable seat valve 827.3, to which the second level compensation container 845 can be supplied with atmospheric pressure in the open position of the seat valve 827.3 downstream of the ventilation part 848 and in the closed position of the seat valve 827.1 downstream of the compressed air reservoir 821 and in the closed position of the seat valve 827.2 downstream of the vacuum pump 833.

The fluid-supply assembly 803 also has a fluid buffer container 851, which is connected to the zenith area of the end chamber 375 via a fluid inlet line 809 and to the end chamber 375 on the sump side via a fluid outlet line 812. The fluid buffer container 851 is designed to supply air to the end chamber 375, but also lubricant if required, in particular for lubricating the end seal 357.

The compressed air reservoir 821 of the fluid-supply assembly 803 is connected to the fluid buffer container 851 via a pneumatic throttle 824.1 and a switchable seat valve 827.1. Thus, when the seat valve 827.1 connected to it is in the open position, the fluid buffer container 851 can be pressurized with pressure originating from the compressed air reservoir 821, specifically a pressure higher than atmospheric pressure, as overpressure.

Furthermore, the vacuum line 830, which is connected to the inlet side of the vacuum pump 833, is connected to the fluid buffer container 851 via a further throttle 824.2 and a further switchable seat valve 827.2. As explained in more detail below, the vacuum pump 833 is designed to apply a predetermined pressure lower than atmospheric pressure to the fluid buffer container 851 as a vacuum in the open position of the seat valve 827.2 located in the vacuum line 830 and in the closed position of the seat valve 827.1 arranged between the compressed air reservoir 821 and the fluid buffer container 851.

Furthermore, it can be seen from the illustration in Fig. 8 that the fluid buffer container 851 is connected to a pressure measuring unit 842 via a

pressure measuring line 836 with an intermediate ball valve 839. The pressure measuring unit 842, which can be connected to the fluid buffer container 851, is designed to measure the pressure prevailing in the fluid buffer container 851 when required.

A ventilation part 848 is connected to the fluid buffer container 851 by interposing a pneumatic throttle 824.3 and a switchable seat valve 827.3, which is used to apply atmospheric pressure to the fluid buffer container 851 in the open position of the seat valve 827.3 downstream of the ventilation part 848 and in the closed position of the seat valve 827.1 downstream of the compressed air reservoir 821, and in the closed position of the seat valve 827.2 downstream of the vacuum pump 833.

The illustration in Fig. 8 also shows that the end chamber 375 is equipped with a liquid outlet 854 in the sump area, which is designed to drain liquid that has accumulated in the end chamber 375 into a collection container 857.

Furthermore, the fluid-supply assembly 803 is equipped with a vacuum storage container 860, which is connected to the vacuum line 830 to compensate for pressure fluctuations. The vacuum storage container 860 is also connected via a pressure measuring line 836 with an intermediate ball valve 839 to a pressure measuring unit 842 in order to determine the average pressure in the vacuum line 830.

It is also useful for the fluid-supply assembly 803 to be equipped with various monitoring sensors, not shown in Fig. 8 for reasons of clarity, for measuring in

particular temperatures, water content, volume flows,
and/or dirt content, which are also advantageously
designed to detect or predict fault conditions and to
emit warning signals when limit values are exceeded or
not reached.

It is also understood that, in one embodiment, the
circulation pumps 815 and the vacuum pump 833 form a
structural unit for a space-saving design.

The fluid-supply assembly 803 is also equipped with a
central control and regulation module 863 which, as
indicated by arrows with two arrowheads, is designed
to receive signals from the components described above
and to control them, respectively, in particular the
throttles 824.1, 824.2, 824.3, seat valves 827.1,
827.2, 827.3, and pressure measuring unit 842, as
explained in more detail below.

If there is support pressure at the working face 112
or if, for example, there is a reference pressure
 p_{ref} in the head chamber 306 that is greater than a
limit pressure p_{limit} , then the fluid-supply assembly
803 is operated in an overpressure mode. A
predetermined target pressure is stored in the control
and regulation module 863 for the first internal
chamber 369, the second internal chamber 372, the end
chamber 375, and the connecting line 381 connected to
the gear chamber. This target pressure depends, for
example, on the atmospheric pressure as the reference
pressure p_{ref} . Typically, the values for the target
pressures are available in a table as a function of
the reference pressure p_{ref} . It applies further that
the reference pressure p_{ref} is greater than the
pressure in the first internal chamber 369, the

pressure in the first internal chamber 369 is greater than the pressure in the second internal chamber 372, the pressure in the second internal chamber 372 is greater than the pressure in the end chamber 375, and
5 the pressure in the end chamber 375 is less than or equal to the pressure in the connecting line 381.

If necessary, the pressure in the gear chamber is higher than the pressure in the end chamber 375 so
10 that the sealing lip 360 of the end seal 357 located between the gear chamber and the end chamber 375 is pressed against it to support the sealing effect.

If the pressure in the first internal chamber 369, the
15 second internal chamber 372, or the end chamber 375 falls below a target pressure, or if the target pressure in the first internal chamber 369, the second internal chamber 372, or the end chamber 375 has not yet been reached, the relevant seat valve 827.1
20 downstream of the compressed air reservoir 821 is opened. This causes compressed air to flow into the first internal chamber 369, the second internal chamber 372, or the end chamber 375 until the required pressure in the first internal chamber 369, the second
25 internal chamber 372, or the end chamber 375 is reached or reached again. The seat valve 827.2 connected in parallel downstream of the vacuum pump 833 is closed during this process.

30 Once the target pressure has been reached, the seat valve 827.1 upstream of the relevant compressed air reservoir 821 is closed and the pressure is maintained.

If the pressure in the first internal chamber 369 rises above the target pressure, for example because the reference pressure p_{ref} drops, the seat valve 827.2 located between the first internal chamber 369 and the vacuum pump 833 is opened, and the vacuum pump 833 sucks air out of the first internal chamber 369 via the throttle 824.2 upstream of the vacuum pump 833 until the target pressure is reached again in the first internal chamber 369. The parallel seat valve 827.1 connected to the compressed air reservoir 821 is closed during this process.

If the pressure in the second internal chamber 372 rises above the target pressure, for example because the reference pressure p_{ref} and/or the pressure in the first internal chamber 369 fall(s), either the seat valve 827.2, which is located between second internal chamber 372 and the vacuum pump 833, is opened, which causes the vacuum pump 833 to extract air from the second internal chamber 372 via the throttle 824.2 upstream of the vacuum pump 833 until the target pressure in the second internal chamber 372 is reached again, or the seat valve 827.3 upstream of the ventilation part 848 is opened and the pressure in the second internal chamber 372 is released when the target pressure in the second internal chamber 372 is atmospheric pressure. The seat valve 827.1 located between the compressed air reservoir 821 and the second internal chamber 372 is closed in both cases.

If the pressure in the end chamber 375 rises above the target pressure, for example because the reference pressure p_{ref} and/or the pressure in the second internal chamber 372 fall(s), the seat valve 827.2 located between the end chamber 375 and the vacuum

pump 833 is opened, and the vacuum pump 833 sucks air out of the end chamber 375 via the throttle 824.2 downstream of this seat valve 827.2 until the target pressure in the end chamber 375 is reached again. The
5 seat valve 827.3 upstream of the ventilation part 848 is closed during this process.

In another procedure, the seat valve 827.3 upstream of the ventilation part 848 is opened and the pressure in
10 the end chamber 375 is released when the target pressure in the end chamber 375 is atmospheric pressure.

The corresponding seat valve 827.1 upstream of the
15 compressed air reservoir 821 is closed in both of the above procedures.

The ventilation part 848 keeps the second internal chamber 872 and/or the end chamber 375 permanently at
20 atmospheric pressure without the need for control. To this end, the seat valves 827.1 upstream of the compressed air reservoir 821 and the seat valves 827.2 upstream of the vacuum pump 833 are closed, and the seat valves 827.3 upstream of the respective
25 ventilation part 848 are opened.

It is preferable that, in the event that the reference pressure p_{ref} is greater than the limit pressure p_{limit} , the pressure in the end chamber 375 is less
30 than or equal to atmospheric pressure. The atmospheric pressure can be adjusted via the respective ventilation part 848.

To reduce the pressure, the seat valves 827.1 upstream
35 of the compressed air reservoir 821 and the seat

valves 827.3 upstream of the ventilation parts 848 are closed, while the seat valves 827.2 upstream of the vacuum pump 833 are opened until the predetermined vacuum has been set as the target pressure. The pressure control then takes place by opening and closing the seat valves 827.2 upstream of the vacuum pump 833 in order to maintain or restore the vacuum. To increase the pressure, the relevant seat valves 827.1 upstream of the compressed air reservoir 821 are opened briefly. The seat valves 827.3 upstream of the ventilation parts 848 are closed during this process.

In another procedure, the overpressure in the first internal chamber 369, the second internal chamber 372, and the end chamber 375 is regulated in such a way that the seat valves 827.2 downstream of the compressed air reservoir 821 and/or, in the case of the second internal chamber 372 or the end chamber 375, the seat valves 827.3 upstream of the ventilation parts 848 are always open, the volume flow in the throttles 824.2, 824.3 respectively assigned to the seat valves 827.2, 827.3 is smaller than the volume flow through the throttles 824.1 arranged between the compressed air reservoir 821 and the respective downstream seat valves 827.1. The seat valves 827.2 upstream of the vacuum pump 833 and the seat valves 827.3 upstream of the ventilation parts 848 are only closed when no compressed air supply is possible. The throttles 824.2, 824.1, 824.3 can be regulated for this purpose.

In yet another procedure, the overpressure in the first internal chamber 369, the second internal chamber 372, and the end chamber 375 is regulated in such a way that the seat valves 827.1, 827.2, 827.3

are closed in each case individually or in combination as required only with a predetermined time delay relative to the other seat valves 827.1, 827.2, 827.3. This occurs when the volume flow through the throttles 824.2 upstream of the vacuum pump 833 or through the throttles 824.3 upstream of the ventilation parts 848 is smaller than the volume flow through the throttles 824.1 upstream of the compressed air reservoir 821.

If there is a support pressure at the working face 112 or if, for example, there is a reference pressure p_{ref} in the head chamber 306 that is less than a limit pressure p_{limit} , then the fluid-supply assembly 803 is operated in a vacuum mode. For this purpose, a predetermined target pressure is stored in the control and regulation module 863 for the first internal chamber 369, for the second internal chamber 372, for the end chamber 375, and for the gear chamber, which is dependent, for example, on the atmospheric pressure as the reference pressure p_{ref} . The values for the target pressures are stored in a table as a function of the reference pressure p_{ref} .

In vacuum mode, too, the reference pressure p_{ref} is greater than the pressure in the first internal chamber 369, the pressure in the first internal chamber 369 is greater than the pressure in the second internal chamber 372, and the pressure in the second internal chamber 372 is greater than the pressure in the end chamber 375.

To improve the sealing effect, vacuum is applied in the first internal chamber 369, in the second internal chamber 372, and in the end chamber 375. To set the vacuum in the first internal chamber 369, in the

second internal chamber 372, and in the end chamber 375, the seat valve 827.2 upstream of the vacuum pump 833 and connected to the first internal chamber 369, the second internal chamber 372, and the end chamber 375, respectively, is opened, and air is sucked out by the vacuum pump 833 until the respective target pressure is reached as a vacuum. The seat valves 827.1 upstream of the compressed air reservoir 821 and the seat valves 827.3 upstream of the ventilation parts 848 are closed.

Once the respective target pressure has been reached, the respective seat valve 827.2 upstream of the vacuum pump 833 is closed and the pressure is maintained in the first internal chamber 369, in the second internal chamber or in the end chamber 375.

If the pressure in the first internal chamber 369, the second internal chamber 372, or the end chamber 375 rises above the target pressure, the corresponding seat valve 827.2 upstream of the vacuum pump 833 opens, and the vacuum pump 833 sucks air through the associated throttle 824.2 until the target pressure is reached again. The respective seat valve 827.1 upstream of the compressed air reservoir 821 and the respective seat valve 827.3 upstream of the ventilation part 848 are closed during this process.

Once the target pressure has been reached again, the respective seat valve 827.2 upstream of the vacuum pump 833 is closed and the pressure is maintained in the first internal chamber 369, in the second internal chamber 372 or in the end chamber 375.

If the pressure in the first internal chamber 369, the second internal chamber 372, or the end chamber 375 now falls below the target pressure, the respective seat valve 827.1 upstream of the compressed air reservoir 821 is opened, and compressed air flows into the first internal chamber 369, the second internal chamber 372, and the end chamber 375, respectively, until the target pressure in the first internal chamber 369, the second internal chamber 372, and the end chamber 375 is reached again. The respective seat valve 827.2 upstream of the vacuum pump 833 and the respective seat valve 827.3 upstream of the ventilation part 848 are closed in this process.

Once the target pressure has been reached, the respective seat valve 827.1 upstream of the compressed air reservoir 821 is closed and the pressure in the first internal chamber 369, the second internal chamber 372 and the end chamber 375 is maintained.

If provided for in vacuum mode, the second internal chamber 372 and/or the end chamber 375 are permanently maintained at atmospheric pressure via the relevant ventilation part 848 without the need for control. For this purpose, the respective seat valves 827.1 upstream of the compressed air reservoir 821 and the seat valves 827.2 upstream of the vacuum pump 833 are closed, and the seat valve 827.3 upstream of the respective ventilation part 848 is opened. The pressure in the gear chamber is higher than the pressure in the end chamber 875 as required so that the sealing lip 860 of the end seal 357 is pressed between the gear chamber and the end chamber 375 to support the sealing effect.

In another procedure in vacuum mode, the vacuum in the first internal chamber 369, the second internal chamber 372, and the end chamber 375 is regulated in such a way that the respective seat valves 827.1 upstream of the compressed air reservoir 821, and/or, in the case of the second internal chamber 372 and the end chamber 375, the respective seat valves 827.3 upstream of the ventilation parts 848 are always open, the respective volume flow in the throttles 824.1 or in the throttles 824.3 upstream of the ventilation parts 848 is smaller than the respective volume flow through the throttles 824.2 upstream of the vacuum pump 833. The seat valves 827.1 upstream of the compressed air reservoir 821 and the throttles 827.3 upstream of the ventilation parts 848 are only closed when air extraction is not possible. The throttles 824.1, 824.2, 824.3 are designed for this purpose.

In yet another procedure in vacuum mode, the vacuum in the first internal chamber 369, the second internal chamber 372, and the end chamber 375 is regulated in such a way that the seat valves 827.1, 827.2, 827.3 are closed individually or in combination with a predetermined time delay relative to the other seat valves 827.1, 827.2, 827.3. This occurs when the volume flow in the respective throttles 824.1 upstream of the compressed air reservoir 821 or in the respective throttles 824.3 upstream of the ventilation parts 848 is smaller than the volume flow through the respective throttles 824.2 upstream of the vacuum pump 833.

In yet another procedure in vacuum mode, the vacuum in the first internal chamber 369, the second internal chamber 372, and the end chamber 375 is adjusted by

controlling the vacuum pump 833. For this purpose, the corresponding seat valve 827.2 upstream of the vacuum pump 833 is opened until the target pressure is set, while the respective seat valves 827.1 upstream of the compressed air reservoir 821 and the respective seat valves 827.3 upstream of the ventilation parts 848 are closed. If the pressure in the first internal chamber 369, the second internal chamber 372, or the end chamber 375 rises, the respective seat valve 827.2 upstream of the vacuum pump 833 is opened, and the vacuum pump 833 sucks air until the target pressure is reached in the first internal chamber 369, in the second internal chamber 372, or in the end chamber 375, respectively.

Figs. 9 to 11 show schematic representations of essential components of the sealing arrangement 212 in the first sealing area 215, which have already been explained in detail above, as well as diagrams showing the pressure conditions prevailing in various mining environments. These pressure conditions can be selectively and predeterminedly adjusted by the interaction described above, in particular in connection with Fig. 8, in dependence on the respective mining conditions.

Fig. 9 shows a schematic representation of the essential components of the sealing arrangement 212 in the first sealing area 215, as well as a diagram showing the pressure conditions that prevail during pressure-assisted advancement with a relatively high support pressure, wherein the diagram shows on the abscissa 903 a distance x from an arbitrary zero point located in front of the head seal 303 in the direction of advance and on an ordinate 906 a pressure p in

arbitrary units relative to a reference pressure p_{ref} , e.g. atmospheric pressure, on the side located behind the end seal 351 in the direction of advance. The diagram in Fig. 9 shows that, compared to the possibly relatively high pressure prevailing in the head chamber 306, a reduced pressure already prevails in the first internal chamber 369 due to its considerable reduction by the head seal 303, which, in the configuration shown in Fig. 9, the pressure in the second internal chamber 372 is already reduced to the reference pressure p_{ref} , which also prevails in the connecting line 381. Due to the same orientation of the head seal 303 and the internal seals 339, 345, loss-free feeding of lubricants into the internal chambers 369, 372 is thus achieved.

In preferred embodiments, the lubricant fed into the first internal chamber 369 is a fluid grease or an oil, while the lubricant fed into the second internal chamber 372 is a fluid grease or an oil.

The term "fluid grease" refers to a medium that has a consistency according to a corresponding consistency index of the NLGI classes 000, 00, 0, or 1 in accordance with DIN 51818, with a flowing, slightly flowing, semi-fluid, or very soft flow behavior.

Furthermore, it can be seen from the illustration in Fig. 9 in conjunction with the explanations for Fig. 8 that the second internal chamber 372 can also serve as a further pressure reduction stage in addition to the first internal chamber 369 or as a replacement pressure reduction stage in the event of a failure of the sealing effect of the first internal chamber 369.

Deviating from the pressure conditions shown in Fig. 9, the pressure conditions explained below can also be set as a function of the respective driving conditions, with variations that can be combined with each other as desired.

In a first variation, the pressure in the second internal chamber 372 is lower than the reference pressure p_{ref} .

In a second variation, the pressure in the end chamber 375 is lower than the reference pressure p_{ref} .

In a third variation, the pressure in the connecting line 381 is higher than the reference pressure p_{ref} .

Fig. 10 shows a representation corresponding to Fig. 9, wherein in Fig. 10 the pressure conditions are shown qualitatively in the diagram for propulsion without support pressure. The representation according to Fig. 10 shows that the pressures in the internal chambers 369, 372 up to the end chamber 375 fall gradually below the reference pressure p_{ref} by connecting the vacuum line 830 according to the explanations in Fig. 8, wherein here too the closing function of the head seal 303, the internal seals 339, 345, and the end seal 351 is ensured by their respective orientation.

In contrast to the pressure conditions shown in Fig. 10, in a variation the pressure in the connecting line 381 is higher than the reference pressure p_{ref} .

Fig. 11 shows a representation corresponding to Fig. 9, wherein in Fig. 11 the pressure conditions with a

relatively low support pressure are qualitatively represented in the diagram. The illustration in Fig. 11 shows that the pressures in the internal chambers 369, 372 up to the end chamber 375 fall gradually below the reference pressure p_{ref} by connecting the vacuum line 830 in accordance with the explanations in Fig. 8, starting from a pressure in the head chamber 306 that is higher than the reference pressure p_{ref} , wherein the pressure in the connecting line 381 is again set higher than the reference pressure p_{ref} and wherein, here too, the closing function of the head seal 303, the internal seals 339, 345, and the end seal 351 is ensured by their respective orientation.

In contrast to the pressure conditions shown in Fig. 11, in a variation the pressure in the connecting line 381 corresponds to the reference pressure p_{ref} .

The pressure cascades explained in Figs. 9 to 11, with a gradual return of the support pressure prevailing in the head chamber 306 to the internal chambers 369, 372 without any intermediate pressure increases, ensure reliable lubrication even in the event of leaks.

The invention is thus based on a predetermined interaction of absolute pressure values, which, due to the preferred choice of low-viscosity lubricants such as fluid grease or oil, and thus deviating from commonly used high-viscosity lubricants such as grease, can be measured relatively easily and sufficiently accurately as explained above, and pressure differences that are set up in such a way that, on the one hand, in contrast to loss lubrication with grease discharge, largely loss-free lubrication is achieved and, on the other hand, a relatively low

load on the sealing arrangement 212, and in particular on the sealing lips 360, is created.

CLAIMS

1. Tunnelling machine having a drive shaft (206)
5 designed to rotate a cutting wheel (109), having
a sealing arrangement (212) designed to seal an
annular gap (333) formed around the drive shaft
(206) between stationary components (309, 336)
and rotating components (309, 384), wherein the
10 sealing arrangement (212) comprises a number of
sealing rings (303, 339, 345, 351) and chamber
rings (330, 342, 348) arranged between the
sealing rings (303, 339, 345, 351), having a
fluid-supply assembly (803) arranged to supply
15 lubricants to the sealing arrangement (212), and
having a number of receiving chambers formed
between adjacent sealing rings (303, 339, 345,
351), comprising a first internal chamber (369)
located at the front in a direction of advance
20 and a second internal chamber (372) located at
the rear of the first internal chamber (369) in a
direction of advance, which can be supplied with
lubricants, **characterized in that** the fluid-
supply assembly (803) is designed to adjust the
25 pressure in the first internal chamber (369) such
that the pressure in the first internal chamber
(369) is lower than the pressure in a sealing
ring (303) located in front of the first internal
chamber (369) in the direction of advance and
30 sealing it against a mining area (112), and
higher than the pressure prevailing in the second
internal chamber (372).
2. Tunnelling machine according to claim 1,
35 characterized in that the fluid-supply assembly

(803) is designed to adjust the pressure in the second internal chamber (372) so that this pressure lies between the pressure in the first internal chamber (369) and the pressure in an end chamber (375) located behind the second internal chamber (372) in the direction of advance.

3. Tunnelling machine according to claim 1 or claim 2, characterized in that the first internal chamber (369) can be selectively pressurized with overpressure or vacuum relative to atmospheric pressure.

4. Tunnelling machine according to claim 3, characterized in that the second internal chamber (372) can be selectively pressurized with atmospheric pressure or with overpressure relative to atmospheric pressure or with vacuum relative to atmospheric pressure.

5. Tunnelling machine according to claim 3 or claim 4, characterized in that a vacuum line (830) and a vacuum pump (833) are provided for applying a vacuum, which are in fluid communication with the respective internal chamber (369, 372).

6. Tunnelling machine according to one of claims 3 to 5, characterized in that a compressed air reservoir (821) is provided for applying overpressure, which is in fluid connection with the respective internal chamber (369, 372).

7. Tunnelling machine according to one of claims 4 to 6, characterized in that a ventilation part (848) is provided for applying atmospheric

pressure, which is in fluid connection with the second internal chamber (372).

- 5 8. Tunnelling machine according to one of claims 1 to 7, characterized in that an end chamber (375) is provided, which is arranged behind the last internal chamber (372) in the direction of advance and can be selectively pressurized with atmospheric pressure or with an overpressure
10 relative to atmospheric pressure or with a vacuum relative to atmospheric pressure.
- 15 9. Tunnelling machine according to claim 8, characterized in that a vacuum line (830) and a vacuum pump (833) are provided for applying a vacuum, which are in fluid connection with the end chamber (375).
- 20 10. Tunnelling machine according to claim 8 or claim 9, characterized in that a compressed air reservoir (821) is provided for applying overpressure, which is in fluid connection with the end chamber (375).
- 25 11. Tunnelling machine according to one of claims 8 to 10, characterized in that a ventilation part (848) is provided for applying atmospheric pressure, which is in fluid communication with the end chamber (375).
30
- 35 12. Tunnelling machine according to one of claims 8 to 11, characterized in that a connecting line (381) is provided, which is arranged at the rear of the end chamber (375) in the direction of advance and can be selectively pressurized with

atmospheric pressure or with an overpressure relative to atmospheric pressure.

- 5 13. Tunnelling machine according to one of claims 1 to 12, characterized in that the fluid-supply assembly (803) is designed to deliver a fluid grease or oil as a lubricant to the first internal chamber (369) and a fluid grease or oil to the second internal chamber (372).
- 10 14. Tunnelling machine according to one of claims 1 to 13, characterized in that the fluid-supply assembly (803) is designed to deliver a fluid grease or oil as a lubricant into the end chamber (375).
- 15 15. Tunnelling machine according to one of claims 1 to 14, characterized in that chamber rings (330, 342) arranged in the internal chambers (369, 372) are formed with an annular groove (363) and with passage recesses (366) located in the apex area relative to gravity.
- 20 16. Tunnelling machine according to claim 15, characterized in that flow brakes (403, 406; 706) are arranged on both sides of an apex area of internal chambers (369, 372).
- 25 17. Tunnelling machine according to one of claims 1 to 16, characterized in that the drive shaft (206) is designed as a hollow shaft and in that the sealing arrangement (212) has a first sealing area (215) arranged radially on the outside and a second sealing area (218) arranged radially on the inside.
- 30 35

18. Method for driving a tunnel, comprising the steps of
- providing a tunnelling machine according to one of claims 1 to 17, and
 - adjusting the pressure in the first internal chamber (369) such that the pressure in the first internal chamber (369) is lower than the pressure in a sealing ring (303) sealing the first internal chamber (369) against a mining area (112) in the direction of advance and higher than the pressure prevailing in the second internal chamber (372).
19. Method according to claim 18, comprising the step of
- adjusting the pressure in the second internal chamber (372) such that the pressure in the second internal chamber (372) is different from a reference pressure (p_{ref}).
20. Method according to claim 19, comprising the step of
- setting the reference pressure (p_{ref}) such that the reference pressure (p_{ref}) is different from atmospheric pressure.
21. Method according to one of claims 18 to 20, insofar as a tunnelling machine according to any one of claims 8 to 12 or according to claim 14 is provided, comprising the step of
- adjusting the pressure in the end chamber (375) such that the pressure in the end chamber (375) is lower than the pressure in the second internal chamber (372).