

Apparatus for driving a tunnel

5 The invention relates to an apparatus for driving a tunnel in accordance with the preamble of claim 1.

Such an apparatus is known from US-A-4,171,848. The previously known apparatus for driving a tunnel in a direction of advance possesses an excavating tool for excavating material from a working face located in the front, viewed in the direction of advance. Arranged to the rear of the excavating tool, viewed in the direction of advance, there is also a working chamber into which a discharge line arrangement opens by means of which the material present in the working chamber can be transported out of the working chamber. The discharge line arrangement is equipped with a discharge volume measuring unit by means of which the volume of material transported out of the working chamber can be measured. In addition, the previously known apparatus is equipped with an evaluation module which is connected with the discharge volume measuring unit and by means of which a discharge volume measurement signal corresponding to the discharge volume is evaluated in order to control the tunnel-driving through adjustment of a support pressure in the region of the excavating tool.

25 The invention is based on the problem of providing an apparatus of the aforementioned type by means of which an excessive transportation of material, in comparison with the quantity of material which is actually to be excavated, can reliably be determined, said excessive transportation being associated with the hazard of a formation of sinkholes.

30 According to the invention, this problem is solved in an apparatus of the aforementioned type with the characterising features of claim 1.

As a result of the fact that, in the apparatus according to the invention, in a bypass mode the volumes flowing in the discharge line arrangement and in the feed line arrangement and the variation over time of the filling level in the working chamber can be measured, the influences of parasitic
5 volume flows, for example non-critical inflow and outflow in the excavation area, leaks in the discharge line arrangement and/or in the feed line arrangement which are common in operation, or inflows and outflows at hydraulic seals, respectively, which are not causally related to the quantity of material actually transported, can be measured and used to adjust the
10 actual discharge volume to an effective discharge volume by excluding parasitic volumes.

Further practical embodiments of the invention are the subject matter of the dependent claims.

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Further practical embodiments and advantages of the invention are explained in the following description of an exemplary embodiment with reference to the figures in the drawing, in which:

20 Fig. 1 shows a schematic view of an exemplary embodiment of an apparatus according to the invention and

Fig. 2 shows a schematic block diagram of an exemplary evaluation module for the exemplary embodiment of an apparatus according to
25 the invention as shown in Fig. 1.

Fig. 1 shows a schematic view of an exemplary embodiment of an apparatus according to the invention in the form of a so-called tunnel boring machine 1, which is set up for driving a tunnel 2 in a direction of
30 advance. For this purpose the tunnel boring machine 1 is equipped, as an excavating tool, with a cutter head 3 which can be driven in a rotary manner in order to excavate material from a front-side working face,

viewed in the direction of advance. Arranged to the rear of the cutter head 3, viewed in the direction of advance, is a working chamber 4 which is separated by a scum board or baffle 5 from an excavation area 6 to the rear of the cutter head 3, viewed in the direction of advance. The baffle 5 has a baffle opening 7 in the floor area, so that material excavated by the cutter head 3 can pass from the excavation area 6 into the working chamber 4.

In the working chamber 4, a working chamber filling level transmitter 9 is for example mounted on a partition wall or bulkhead 8 opposite the baffle 5, viewed in an axial direction contrary to the direction of advance, which is connected to a working chamber filling level sensor 10 of a working chamber filling level measuring unit. The working chamber filling level sensor 10 allows the filling level 11 of a mixture of substances consisting of liquid and solid components present in the working chamber 4 during an excavation operation to be measured.

The tunnel boring machine 1 according to the exemplary embodiment shown in Fig. 1 is equipped with a feed line arrangement 12 which includes a main feed line 13. The rear end of the main feed line 13, viewed in the direction of advance, is fluid-mechanically connected with a material preparation unit 14. Feed slurry can be pumped out of the material preparation unit 14 in the direction of the working chamber 4 by means of a main feed line pump 15 arranged in the main feed line 13 downstream of the material preparation unit 14. The density and volume of the feed slurry issuing from the material preparation unit 14 can be measured, respectively, by means of a feed line density sensor 16 of a feed density measuring unit of the feed line arrangement 12 and by means of a feed line volume sensor 17 of a feed volume measuring unit of the feed line arrangement 12, respectively.

The feed line arrangement 12 typically includes a feed line extension

section 18 arranged between the working chamber 4 and the material preparation unit 14 by means of which the length of the main feed line 13 can be extended in line with the installation of lining segments 19 at the rear end of a shield skin 20 of the tunnel boring machine 1, viewed in the direction of advance, and shortened again when the rear part of the tunnel boring machine 1, viewed in the direction of advance, is moved up.

In the case of this exemplary embodiment, the main feed line 13 divides between the working chamber 4 and the feed line extension section 18, branching into a first feed line arm 21 and a second feed line arm 22, which both open into the working chamber 4. A first feed line shut-off valve 23 is installed in the first feed line arm 21 downstream of the branching, and a first feed line arm pump 24 is installed after the first feed line shut-off valve 23 in the direction of the working chamber 4. Correspondingly, a second feed line shut-off valve 25 is installed in the second feed line arm 22 downstream of the branching, and a second feed line arm pump 26 is installed after the second feed line shut-off valve 25 in the direction of the working chamber 4. The feed line arm pumps 24, 26 serve to support the main feed line pump 15 in delivering feed slurry into the working chamber 4. The working chamber 4 and the feed line arm pumps 24, 26 can be shut off fluid-mechanically from the feed line arms 21, 22 and thus from the feed line arrangement 12 by means of the feed line shut-off valves 23, 25.

The tunnel boring machine 1 is also equipped with a discharge line arrangement 27 which includes a discharge line 28 running between the working chamber 4 and the material preparation unit 14. Installed in the discharge line 28, adjacent the working chamber 4, is a discharge line shut-off valve 29, and downstream of the discharge line shut-off valve 29 a discharge line pump 30. The working chamber 4 can be shut off fluid-mechanically from the discharge line 28 and thus from the discharge line arrangement 27 by means of the discharge line shut-off valve 29, whereas when the discharge line shut-off valve 29 is open, the mixture present in

the excavation chamber 4 during excavation operations can be transported from the excavation chamber 4 into the material preparation unit 14 by means of the discharge line pump 30.

- 5 Arranged fluid-mechanically between the feed line shut-off valves 23, 25 upstream of the branching together with the discharge line shut-off valve 29 on the one hand and the main feed line pump 15 together with the discharge line pump 30 on the other hand is a bypass line 31 of a bypass line arrangement 32 which directly connects together the main feed line 13
10 and the discharge line 28. The bypass line arrangement 32 is also equipped with a bypass line shut-off valve 33 which is installed in the bypass line 31 and by means of which the bypass line 31 can be shut off.

- Between the discharge line pump 30 and the material preparation unit 14,
15 the discharge line arrangement 27 includes a discharge line extension section 34 by means of which, as in the case of the feed line extension section 18, the length of the discharge line 28 can be extended in line with the installation of the lining segments 19 and shortened again when the rear part of the tunnel boring machine 1, viewed in the direction of
20 advance, is moved up.

- Integrated in the discharge line 28 downstream of the discharge line extension section 34 are a discharge line volume sensor 35 of a discharge volume measuring unit and a discharge line density sensor 36 of a
25 discharge density measuring unit by means of which the volume and density, respectively, of a discharge volume transported in the discharge line 28 in the direction of the material preparation unit 14 can be measured.

- 30 Finally, it can be seen from the schematic representation in Fig. 1 that an evaluation module 37 is provided to which the feed line density sensor 16, the feed line volume sensor 17, the feed line shut-off valves 23, 25, the

discharge line shut-off valve 29, the bypass line shut-off valve 33, the discharge line volume sensor 35 and the discharge line density sensor 36 are connected in terms of signalling technology via signal lines.

- 5 Fig. 2 shows, in a schematic block diagram, the evaluation module 37 for the exemplary embodiment of an apparatus according to the invention as shown in Fig. 1 with the components connected to the evaluation module 37 via signal lines, namely the working chamber filling level sensor 10, the feed line density sensor 16, the feed line volume sensor 17, the feed line
10 shut-off valves 23, 25, the discharge line shut-off valve 29, the bypass line shut-off valve 33, the discharge line volume sensor 35 and the discharge line density sensor 36.

The signal lines from the feed line shut-off valves 23, 25 and the discharge
15 line shut-off valve 29 are connected to input sides of directly functioning, non-inverting logic signal converters 38, 39, 40, so that, when the feed line shut-off valves 23, 25 are open and the discharge line shut-off valve 29 is open, the non-inverting logic signal converters 38, 39, 40 each emit a high-level output signal, whereas when the feed line shut-off valves 23, 25
20 are closed and the discharge line shut-off valve 29 is closed the non-inverting logic signal converters 38, 39, 40 each emit a low-level output signal.

The output sides of the logic signal converters 38, 39, 40 are connected to
25 a valve position recognition member 41 which uses an AND logic which has a high-level output signal precisely when all the logic signal converters 38, 39, 40 each have a high-level output signal in the case where the feed line shut-off valves 23, 25 and the discharge line shut-off valve 29 are opened.

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The signal line from the bypass line shut-off valve 33 is connected to an input side of an indirectly functioning, inverting logic signal converter 42,

so that when the bypass line shut-off valve 33 is open the inverting logic signal converter 42 emits a low-level output signal, whereas when the bypass line shut-off valve 33 is closed the inverting logic signal converter 42 emits a high-level output signal.

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The feed line volume sensor 17 and the discharge line volume sensor 35 are each, respectively, connected via a signal line to input sides of a directly functioning, non-inverting logic signal converter 43, 44. On the output side, the logic signal converters 43, 44 are connected with a
 10 volume flow recognition member 45 which uses an AND logic which has a high-level output signal on the output side precisely when both the feed line volume sensor 17 and also the discharge line volume sensor 35 detect a minimum flow, the limit value of which is predetermined, of feed slurry in the main feed line 13 and discharge slurry in the discharge line
 15 28.

The feed line density sensor 16 and the discharge line density sensor 36 are, on the one hand, connected via their signal lines with a density comparison member 46 which has a high-level output signal precisely
 20 when the difference in the output signals of the feed line density sensor 16 and the discharge line density sensor 36 lies below a threshold corresponding to a predetermined lower limit value for the density difference.

25 The valve position recognition member 41, the inverting logic signal converter 42, the volume flow recognition member 45 and the density comparison member 46 are connected on the output side to an operating mode determining unit 47 which, depending on the output signals of the valve position recognition member 41, of the inverting logic signal
 30 converter 42 and of the volume flow recognition member 45, emits two types of output signals.

A first type of an output signal of the operating mode determining unit 47 is characteristic of a tunnel-driving mode in which, on the one hand, the feed line shut-off valves 23, 25 and the discharge line shut-off valve 29 are open, whereas the bypass line shut-off valve 33 is closed, and on the other hand, both in the main feed line 13 and also in the discharge line 28, in each case a minimum flow as well as, during the relevant excavation phase, a density difference which is greater in comparison with the limit value for density difference are present which is typical of a certain proportion of excavated material in the discharge slurry.

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A second type of an output signal of the operating mode determining unit 47 is characteristic of a bypass mode in which, on the one hand, the feed line shut-off valves 23, 25 and the discharge line shut-off valve 29 are closed, whereas the bypass line shut-off valve 33 is open, and on the other hand, both in the main feed line 13 and also in the discharge line 28, in each case a minimum flow as well as a density difference which is smaller than or at most equal to the limit value for density difference are present which is typical of an absence of excavated material in the discharge slurry.

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The operating mode determining unit 47 is connected via a signal line with a volume correction value determining unit 48 to which the feed line volume sensor 17 and the discharge line volume sensor 35 are in turn connected by means of measured value lines. The operating mode determining unit 47 is also connected via a signal line to a density correction value determining unit 49 to which the feed line density sensor 16 and the discharge line density sensor 36 are in turn connected by means of measured value lines. In addition, the operating mode determining unit 47 is connected via a signal line with a filling level fluctuation correction value determining unit 50, to which the working chamber filling level sensor 10 is in turn connected by means of a measured value line.

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During a driving-free bypass mode between excavation phases in which no excavation and transportation of material takes place, for example during the installation of lining segments 19, the working chamber 4 is shut
 5 off fluid-mechanically from the feed line arrangement 12, the discharge line arrangement 27 and the bypass line arrangement 32. As explained below, this operating mode can be used to determine correction values to allow a reliable determination of the volume excavated and transported through the discharge line arrangement 27 during tunnel-driving, as well as the
 10 associated mass.

On the one hand, in the bypass mode, an increase in volume or a reduction in volume in the feed line arrangement 12 and/or the discharge line arrangement 27 which, for example, can occur through leakages or
 15 through the use of hydraulic sealants, can be detected by means of the volume correction value determining unit 48. In the bypass mode, these volume changes, occurring outside of the excavation chamber 6 and thus not induced through the excavation, can in this way be measured in isolation, separated, in terms of measurement, from volume changes
 20 induced through excavation and represented in the form of a first volume correction value.

Also, during the bypass mode, changes in the filling level 11 in the working chamber 4 measured by the working chamber filling level sensor 10 are
 25 induced solely through the inflow or outflow of slurry in the excavation area 6, so that a second volume correction value can be determined from this by means of the filling level fluctuation correction value determining unit 50.

30 Finally, in the bypass mode, relative density changes between the feed line arrangement 12 and the discharge line arrangement 27 can be determined by means of the density correction value determining unit 49

by comparing the measured values from the feed line density sensor 16 as well as from the discharge line density sensor 36 and represented in the form of a density correction value.

- 5 Finally, it can be seen from the representation according to Fig. 2 that the evaluation module 37 includes a quantity balance determining unit 51 to which, on the one hand, the operating mode determining unit 47 which determines the current operating mode of the shield boring machine 1 as well as the volume correction value determining unit 48, the density
10 correction value determining unit 49 and the filling level fluctuation correction value determining unit 50 are connected, via which the volume correction values and the density correction value can be fed in.

Practically, an inhibition signal can also be fed to the quantity balance
15 determining unit 51 if volume changes in the feed line arrangement 12 and in the discharge line arrangement 27 occur due to changes in the feed line extension section 18 and in the discharge line extension section 34. As a result, such only brief volume changes which typically occur in operation are not taken into consideration.

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On the basis of the volume correction values, and taking into consideration the wear on the excavating tool, in this exemplary embodiment of the cutter head 3, as well as, in this exemplary embodiment, on the basis of the density correction value, realistically corrected volumes and masses
25 actually excavated and transported during the course of tunnelling can be determined with the quantity balance determining unit 51.

Also, by taking into consideration geometrical and dynamic excavation parameters, namely the excavation cross section of the tunnel boring
30 machine 1 and its tunnel-driving speed, a nominal volume which is to be excavated can be determined.

By comparing the nominal volume with the corrected volume actually excavated and transported, significant increases in the transported volumes and masses in comparison with regular excavation operations, which happen, in particular, when sinkholes occur, are reliably distinguished from non-critical increases and/or fluctuations resulting from operations and are recognised as a hazard situation.

Practically, an alarm arrangement, which is not shown, is provided which, when such a hazard situation is recognised by the quantity balance determining unit 51, generates an alarm signal and/or initiates securing measures to stabilise the hazard situation such as increasing the support pressure in the excavation area 6.

CLAIMS

1. Apparatus for driving a tunnel (2) in a direction of advance, with an excavating tool (3) for excavating material from a working face located in the front, viewed in the direction of advance, with a working chamber (4) arranged to the rear of the excavating tool (3), viewed in the direction of advance, with a discharge line arrangement (27) which opens into the working chamber (4), by means of which the material present in the working chamber (4) can be transported out of the working chamber (4) and which is equipped with a discharge volume measuring unit (35), and with an evaluation module (37) which is connected with the discharge volume measuring unit (35) and by means of which a discharge volume measurement signal corresponding to the discharge volume can be evaluated in order to control the tunnel-driving, **characterised in** that a feed line arrangement (12) is provided which opens into the working chamber (4), by means of which feed slurry can be fed into the working chamber (4) and which is equipped with a feed volume measuring unit (17), that the discharge line arrangement (27) comprises at least one discharge line shut-off valve (29) and the feed line arrangement (12) comprises at least one feed line shut-off valve (23, 25), that a bypass line arrangement (32) is arranged, viewed in the direction of advance, to the rear of the discharge line shut-off valve (29) and the discharge line shut-off valves (29), respectively, as well as, viewed in the direction of advance, to the rear of the feed line shut-off valve (23, 25) and the feed line shut-off valves (23, 25), respectively, which fluid-mechanically connects the discharge line arrangement (27) and the feed line arrangement (12) and which comprises at least one bypass line shut-off valve (33), that a working chamber filling level measuring unit (9, 10) is provided by means of which the filling level (11) in the working chamber (4) can be measured, that

the feed volume measuring unit (17), the working chamber filling level measuring unit (9, 10), the or each discharge line shut-off valve (29), the or each feed line shut-off valve (23, 25) and the or each bypass line shut-off valve (33) are connected with the evaluation module (37) and that the evaluation module (37) is set up, in the closed state of the or each discharge line shut-off valve (29) as well as in the closed state of the or each feed line shut-off valve (23, 25) and in the open state of the or each bypass line shut-off valve (33), to determine, from a volume difference between the volumes flowing in the discharge line arrangement (27) and in the feed line arrangement (12) as well as the change over time of the filling level (11) in the working chamber (4), correction values for calculating the quantity of material actually excavated during a tunnel-driving operation.

2. Apparatus according to claim 1, characterised in that the evaluation module (37) is equipped with an operating mode determining unit (47) by means of which, when the discharge line shut-off valve (29) is closed and the discharge line shut-off valves (29) are closed, respectively, and also the feed line shut-off valve (23, 25) and the feed line shut-off valves (23, 25) are closed, respectively, and the bypass line shut-off valve (33) and the bypass line shut-off valves (33) are open, respectively, an output signal typical of a bypass mode can be generated.

3. Apparatus according to claim 2, characterised in that the correction values comprise two volume correction values, wherein one volume correction value is representative of volume changes in the discharge line arrangement (27) as well as in the feed line arrangement (12) which are typically encountered during operation, and a further volume correction value for volume changes in the working chamber (4) which are typically encountered during

operation.

4. Apparatus according to claim 2 or claim 3, characterised in that the discharge line arrangement (27) is equipped with a discharge density measuring unit (36) and the feed line arrangement (12) is equipped with a feed density measuring unit (16) by means of which the density of discharge slurry in the discharge line arrangement (27) and the density of feed slurry in the feed line arrangement (12) can, respectively, be measured.
5. Apparatus according to claim 4, characterised in that the discharge density measuring unit (36) and the feed density measuring unit (16) are connected with a density comparison member (46) which is connected with the operating mode determining unit (47), by means of which a density difference between the discharge slurry and feed slurry can be determined and fed to a density correction value determining unit (49) in order to determine a density correction value.
6. Apparatus according to claim 4 or 5, characterised in that the evaluation module (37) is set up to use the density correction value to determine the mass of excavated and transported material.