WE CLAIM:

1. Method for milling off layers of an asphalt or concrete traffic surface with a milling machine (3) removing the ground surface,

- by milling the ground surface along a predetermined milling track having a predetermined length,

- by transporting the milled material via a conveying device (2) to at least one container of a truck (1) that travels along next to the milling machine (3), said truck (1) having a predetermined maximum loading volume per load, and

- by replacing a fully loaded truck with an unloaded truck when the maximum loading volume of a load has been reached,

c h a r a c t e r i z e d b y

- controlling the travel speed or the current position of the truck (1) as a function of
- the cutting depth and cutting width of the milling machine (3), the maximum payload of the truck (1) and the density of the milled material, and
  - the advance speed of the milling machine (3) or ,
  - the current discharge position of the transport device

2. Method as claimed in claim 1, wherein regulating the loading process by controlling the travel speed of the truck (1) as a function of the advance speed of the milling machine (3) and of the measured loading condition of a container.

3. Method as claimed in one of the claims 1 or 2, wherein controlling the travel speed or the current position of the truck (1) as a function of the

advance speed of the milling machine (3), or of the distance travelled by the milling machine (3) in the current milling track, or of the current discharge position of the transport device.

4. Method as claimed in one of the claims 1 to 3, wherein controlling the travel speed or the current position of the truck (1) in such a fashion that the discharge position of the conveying device above the at least one container moves from a front or rear end position inside the container to an end position that is opposite in longitudinal direction.

5. Method as claimed in one of the claims 1 to 4, wherein controlling the travel speed of the truck (1) in such a fashion that the travel speed of the truck is higher than or equal to the advance speed of the milling machine (3).

6. Method as claimed in one of the claims 1 to 5, wherein controlling the travel speed of the truck (1) in such a fashion that the travel speed of the truck (1) shows a constant positive difference to the advance speed of the milling machine (3).

7. Method as claimed in one of the claims 1 to 6, wherein controlling the travel speed of the truck (1) in such a fashion that the travel speed of the truck is altered in a discontinuous fashion.

8. Milling machine (3) with a control unit for controlling the removal process during the mining of milled material during the milling off of layers of an asphalt or concrete traffic surface, and for controlling the transporting away of the removed milled material for loading onto a truck (1), where the milling machine

   - removes the ground surface along a predetermined milling track having a predetermined length,
   - conveys the milled material via a conveying device to at least one container of a truck (1) that travels along next to the milling machine, said truck having a predetermined maximum loading volume per load, and where
   - a fully loaded truck is replaced with an unloaded truck when the

maximum loading volume of a truck load has been reached,

c h a r a c t e r i z e d i n t h a t

the control unit controls the travel speed or the current position of the truck (1) as a function of

- the cutting depth and cutting width of the milling machine (3), the maximum payload of the truck and the density of the milled material, and
- -the advance speed of the milling machine (3) or
- the current discharge position of the transport device.

9. Milling machine (3) as claimed in claim 8, wherein the control unit regulates the loading process of at least one container by controlling the travel speed of the truck (1) as a function of the advance speed of the milling machine (3) and of the measured loading condition of the container.

10. Milling machine (3) as claimed in one of the claims 8 or 9, wherein the control unit controls the travel speed or the current position of the truck as a function of the advance speed of the milling machine (3), or of the distance travelled by the milling machine (3) in the current milling track, or of the current discharge position of the transport device in relation to the truck (1).

11. Milling machine (3) as claimed in one of the claims 8 to 10, wherein the control unit controls the travel speed or the current position of the truck (1) in such a fashion that the discharge position of the conveying device (2) above the at least one container moves from a front or rear end position inside the container to an end position that is opposite in longitudinal direction.

13. Milling machine (3) as claimed in one of the claims 8 to 11, wherein the

control unit controls the travel speed of the truck in such a fashion that the travel speed of the truck is higher than or equal to the advance speed of the milling machine.

14. Milling machine (3) as claimed in one of the claims 8 to 13, wherein the control unit controls the travel speed of the truck (1) in such a fashion that the travel speed of the truck (1) shows a constant positive difference to the advance speed of the milling machine.

15. Milling machine (3) as claimed in one of the claims 8 to 14, wherein the control unit alters the travel speed of the truck in a discontinuous fashion.

Dated this 17th day of April, 2014

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(RP Bhattacharya)
REG. NO.: IN/PA-60
Of De Penning & De Penning
Agent for the Applicants

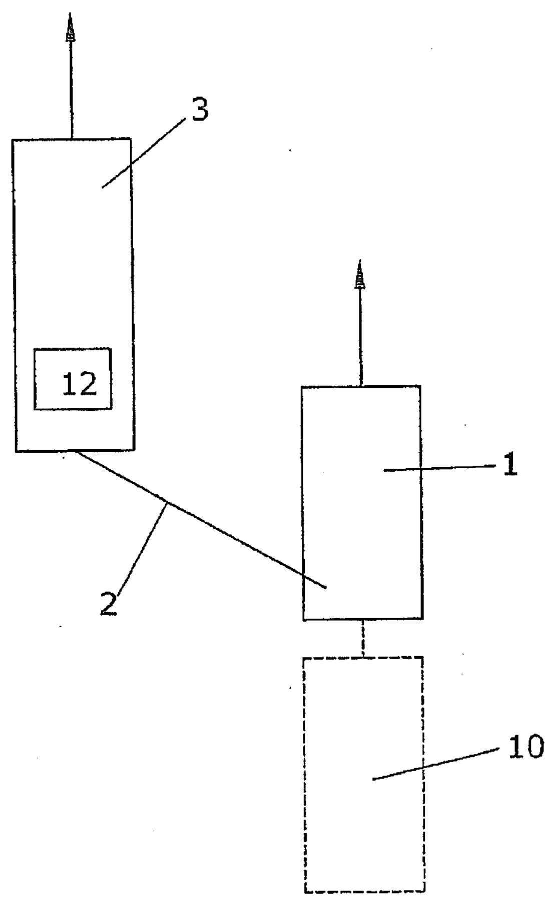

Fig.1

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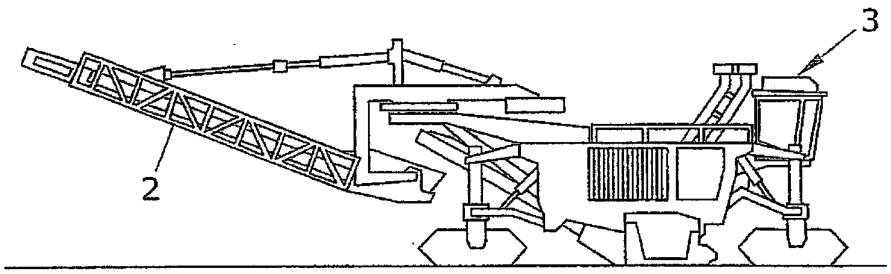

Fig.2

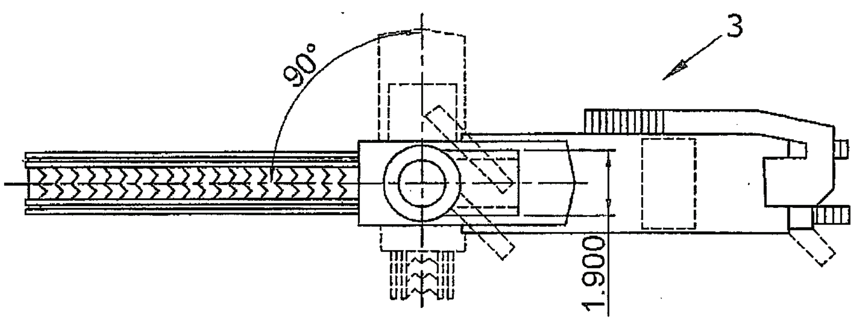

Fig.3

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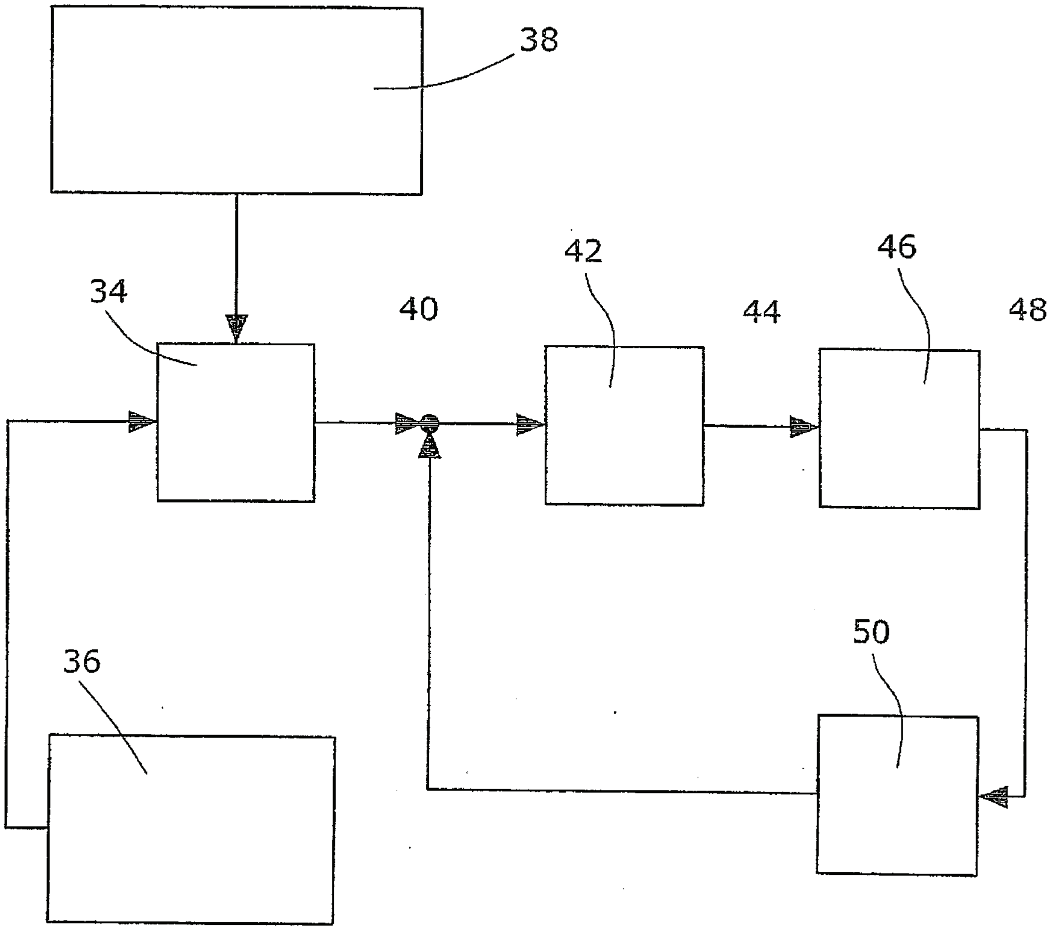

Fig.4

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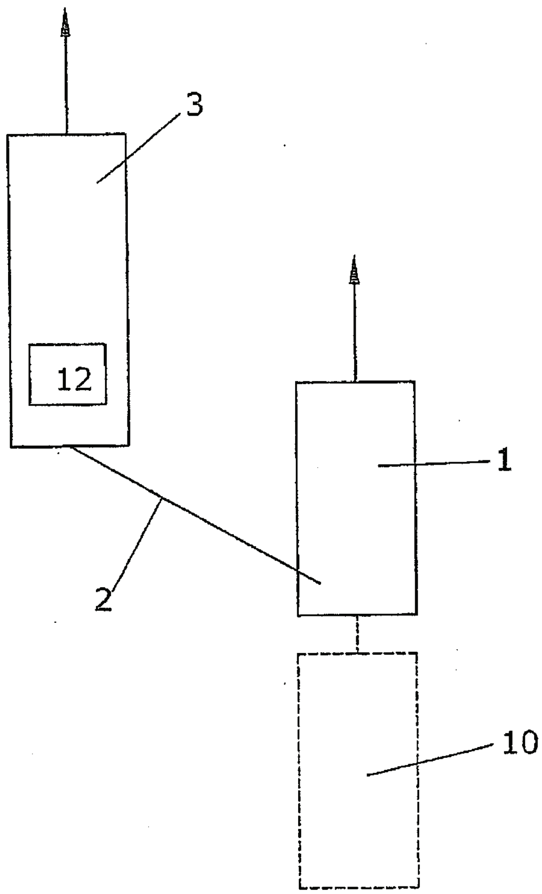

Fig.1

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Wirtgen GmbH

Sheets: 3
No. of Sheet: 2

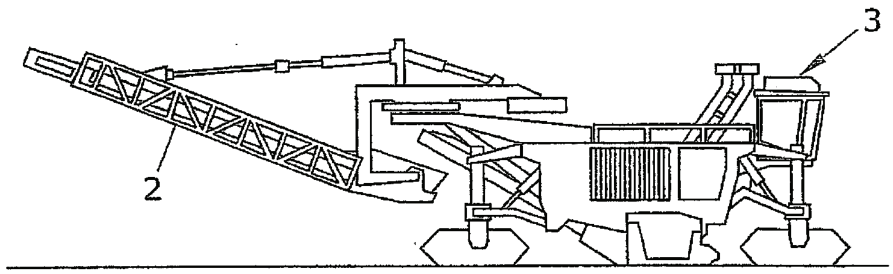

Fig.2

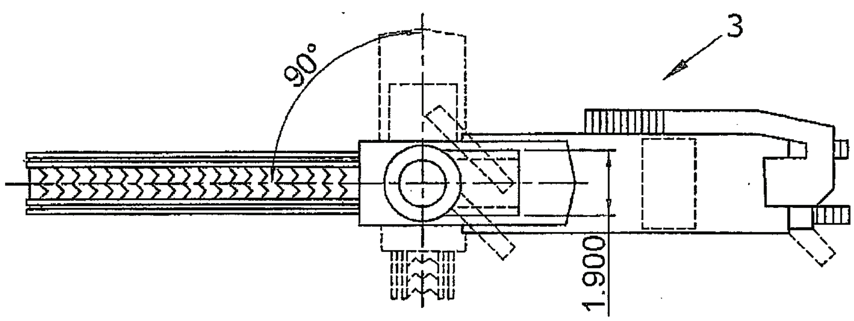

Fig.3

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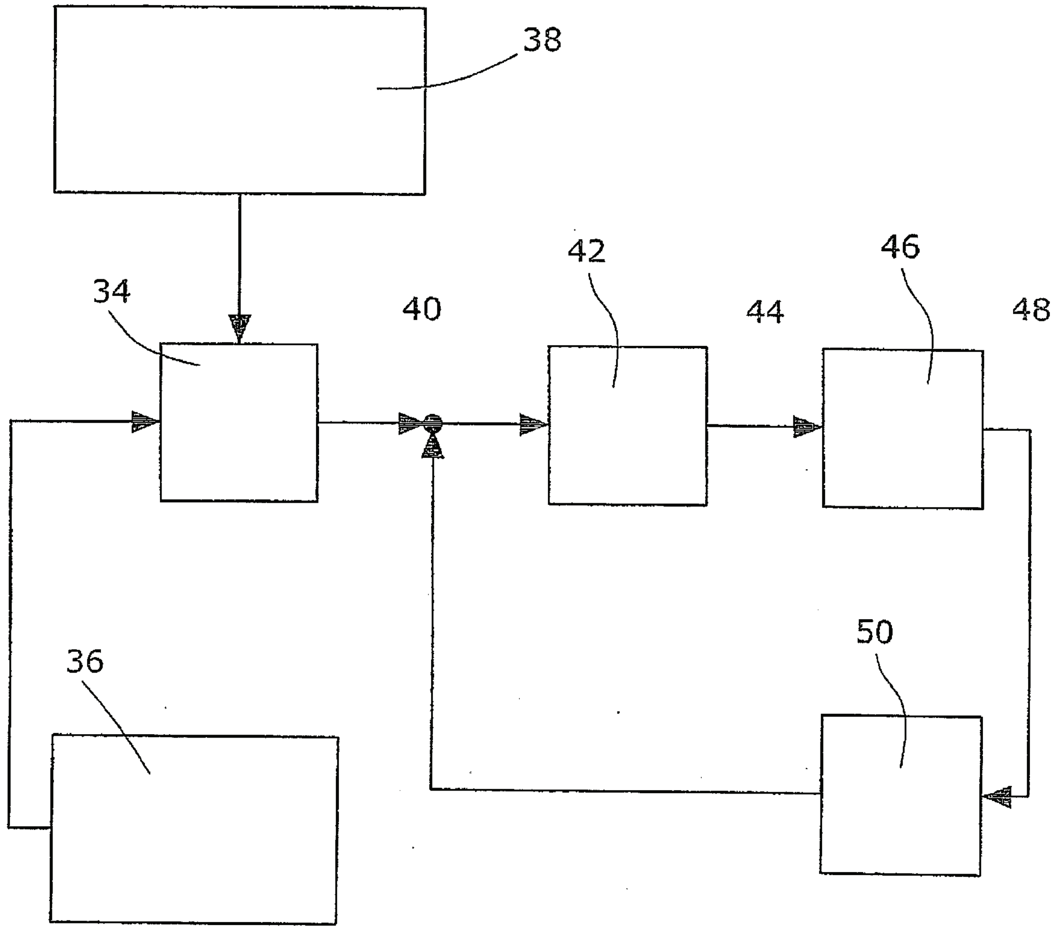

Fig.4

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FORM 2

THE PATENTS ACT, 1970
(39 of 1970)
AND
THE PATENTS RULES, 2003

COMPLETE SPECIFICATION

(See Section 10; rule 13)

T I T L E

"MILLING MACHINE AS WELL AS METHOD FOR MILLING"

APPLICANT

Wirtgen GmbH, Reinhard-Wirtgen-Strasse 2, 53578 Windhagen, Germany;
Nationality: Germany

The following specification particularly describes
the invention and the manner in which
it is to be performed

Milling machine as well as method for milling

FIELD OF THE INVENTION:

The invention relates to a method in accordance with claims 1 and 3 respectively, as well as to a milling machine in accordance with claims 9 and 11 respectively.

BACKGROUND OF THE INVENTION:

The milling machine is able to crush the milled material to such a small size that it can be processed without any or requiring only minor subsequent treatment. The material removed by a milling drum is loaded, via loading conveyors, onto a truck that travels along next to the milling machine. In the process, the milled material is cut, crushed and finally loaded.

A known method provides that the ground surface is milled along a predetermined milling track having a predetermined length. In the process, the milling operation is optimized, in terms of milling depth and milling speed, in accordance with the machine's power and the type of material to be milled.

The milled material is transported via a conveying device to at least one container of a truck that travels along next to the milling machine, said truck having a predetermined maximum loading volume per load. Once the truck is fully loaded, it is replaced with an unloaded truck.

A further problem lies in loading the container of a truck evenly in order to be able to make maximum use of the container volume.

OBJECT OF THE INVENTION

It is therefore the object of the present invention to specify a method for milling a surface that can be performed with greater economic efficiency.

The above mentioned object is achieved by the features of claims 1, 3, 9 and 11.

SUMMARY OF THE INVENTION:

To this end, the following is provided in accordance with the method according to the present invention:

- controlling the travel speed of the truck as a function of the advance speed of the milling machine in such a fashion that the loading space of the at least one container is loaded evenly and fully over the length up to the maximum loading volume.

According to an alternative method the invention provides:

- controlling the travel speed or the current position of the truck as a function of the advance speed of the milling machine, or of the distance travelled by the milling machine in the current milling track, or of the current discharge position of the transport device.

In order to improve the effectiveness of the milling process and the even loading of the container, it may be provided that the travel speed of the truck is controlled, as a function of the advance speed of the milling machine, in such a fashion that the loading space of the at least one container is loaded evenly and fully over the length up to the maximum loading volume.

This is preferably effected by regulating the loading process by means of controlling the travel speed of the truck as a function of the advance speed of the milling machine and of the measured loading condition of a container.

The travel speed or the current position of the truck may alternatively be controlled as a function of the advance speed of the milling machine, or of the distance travelled by the milling machine in the current milling track, or of the current discharge position of the transport device.

It may further be provided that the travel speed or the current position of the truck is controlled in such a fashion that the discharge position of the conveying device above the at least one container moves from a front or rear end position inside the container to an end position that is opposite in longitudinal direction.

The travel speed of the truck is preferably controlled in such a fashion that the travel speed of the truck is higher than or equal to the advance speed of the milling machine.

It may alternatively be provided that the travel speed of the truck is controlled in such a fashion that the travel speed shows a constant positive difference to the advance speed of the milling machine.

It may alternatively be provided that the travel speed of the truck is controlled in such a fashion that the travel speed of the truck is altered in a discontinuous fashion.

At the beginning of the loading process, it may be provided that controlling the travel speed of the truck at a higher travel speed than the advance speed of the milling machine begins only after a sufficiently high initial fill has been discharged at the front or rear end position.

BRIEF DESCRIPTION OF THE DRAWINGS:

In the following, one embodiment of the invention is explained in greater detail with reference to the drawings.

The following is shown:

Fig. 1 loading of a container of a truck via a transport conveyor of the milling machine,

Fig. 2 a side view of a milling machine,

Fig. 3 a top view of a milling machine, and

Fig. 4 a basic structure of a truck control unit.

DETAILED DESCRIPTION:

As can be seen from Fig. 1, the milled material removed by a milling machine, e.g. a surface miner 3, is loaded via a transport conveyor 2 onto a truck 1 that may also be provided with one or several containers 10. A container is located on the truck 1, said container having a loading volume of, for instance, 100 t. Truck and trailer combinations with a total number of three containers of 100 t each mounted on trailers are frequently used, so that the total loading capacity of such a truck load may amount to approx. 300 t. When a truck with a 100 t container is used, changing of the trucks needs to be performed approx. 16 to 17 times over the length of a milling track of approx. 500 m. This means that a short break in operation during changing of the trucks is required after every 30 m already, as the transport conveyor needs to be stopped and, due to the high milling power of the milling machine, the milling process thus also needs to be interrupted briefly during changing of the vehicles.

Fig. 2 shows a milling machine 3 that is provided with a control unit 12 for controlling the removal process during the mining of milled material of an opencast mining surface or during the milling off of layers of an asphalt or concrete traffic surface, and for controlling the transporting away of the removed milled material for loading onto a truck.

The ground surface is removed along a predetermined milling track having a predetermined length.

The milled material is conveyed via a conveying device, for instance, a transport conveyor 2, to at least one container of a truck 1 that travels along next to the milling machine, said truck 1 having a predetermined maximum loading volume per load.

A fully loaded truck is replaced with an unloaded truck when the maximum loading volume of a truck load has been reached.

The control unit 12 can set the advance speed of the milling machine to a preselected milling power, preferably maximum milling power.

In addition, the control unit 12 can control the travel speed of the truck as a function of the advance speed of the milling machine in such a fashion that the loading space of the at least one container is loaded evenly and fully over the length up to the maximum loading volume.

The control unit 12 can regulate the loading process of at least one container by controlling the travel speed of the truck as a function of the advance speed of the milling machine and of the measured loading condition of the container.

The control unit 12 can alternatively control the travel speed or the current position of the truck as a function of the advance speed of the milling machine, or of the distance travelled by the milling machine in the current milling track, or of the current discharge position of the transport device in relation to the truck.

In this arrangement, the control unit 12 can control the travel speed or the current position of the truck in such a fashion that the discharge position of the conveying device above the at least one container moves from a front or rear end position inside the container to an end position that is opposite in longitudinal direction.

Preferably, the control unit can control the travel speed of the truck in such a fashion that the travel speed of the truck is higher than or equal to the advance speed of the milling machine.

The control unit 12 can also increase the travel speed of the truck only after a sufficiently high initial fill has been reached at the front or rear end position.

The fundamental advantage of the following control concept lies in the fact that a continuous loading process between truck and milling machine, where both machines travel at a constant speed, is especially easy to realize with regard to the control concept and requires almost no communication between the milling machine and the truck (except at the beginning and at the end of the loading process).

The principle of the present invention consists in controlling the truck speed and direction as a function of the actual position and speed of the milling machine (or of the position and speed of the conveyor belt of the milling machine respectively), the cutting depth and cutting width of the milling machine and other process parameters known in advance, such as the maximum payload of the truck, the equivalent loading length of the truck and the density of the milled material.

Control law for the truck speed:

General definitions and relations:

Known process parameters and variables:

F_T in $[m]$: cutting depth

F_B in $[m]$: cutting width

v_{SM} in $[m/\min]$: advance speed of the milling machine

M_{pay} in $[t]$: payload of the truck

L in $[-]$: loosening factor, relation between the density of the cut material and the density of the loaded material

ρ_{mat} in $[t/m^3]$: density of the mined material

l_{lc} in $[m]$: equivalent loading length of the truck

Unknown process variables to be determined (in the sequence of clarification):

t_{lc} in $[\min]$: truck loading time

Q_{lc} in $[m^3]$: material volume for one loading cycle

$\dot{q}$ in $[m^3/\min]$: material flow rate from the milling machine

$A_{tray,cr}$ in $[m^2]$: loadable cross-sectional area of the truck tray

v_{Truck} in $[m/\min]$: truck speed in forward direction

Where: [min]: minutes [*m*]: metres [m^3/min]: cubic metres per minute

The truck-loading cross-sectional area as a function of the surface milling machine speed, the cutting depth, the cutting width and the truck speed can be calculated by using the following simple assumptions and relations:

- The material can be loaded onto the truck without any angle of repose.
- The truck 1 and the milling machine 3 travel at a constant speed.
- The truck 1 starts loading at the front end of the truck tray and travels faster than the milling machine.
- There is no storage of material in the milling machine 3.

- A constant loosening of the cut material takes place, i.e. the material delivered by the conveying device equals the cut material, multiplied by the loosening factor.

The material delivered by the milling machine 3 during a specific loading time t_{lc} can be calculated from

$$Q_{lc} = F_T \cdot F_B \cdot v_{SM} \cdot L \cdot t_{lc} = \dot{q} \cdot t_{lc} \, .$$

The resulting cross-sectional loading area of the truck tray can be calculated from

$$A_{tray,cr} = Q_{lc} / l_{lc}$$

where l_{lc} represents an equivalent loading length assuming that the load deposited on the truck resembles a cuboid.

By substituting the material volume and the loading length one obtains

$$A_{tray,cr} = F_T \cdot F_B \cdot L \cdot \frac{v_{SM}}{v_{Truck} - v_{SM}} \, , \qquad (1)$$

which means that for a given cutting depth, a given cutting width and a given loosening factor the cross-sectional loading area is a function of the milling machine speed and the difference of milling machine speed and truck speed. This relation can be verified quite easily. Assuming that the truck is stationary (V_{truck} = 0), it results from the aforementioned relation that

$$A_{tray,cr} = F_T \cdot F_B \cdot L \, ,$$

which means that the material cross-section to be cut by the milling machine, multiplied by the loosening factor, needs to be stored in the truck 1.

To be able to obtain a particular cross-sectional loading area of the truck tray, equation (1) produces a control law for adjusting the truck speed and/or the milling machine speed for a given cutting depth and cutting width. In practice, the loading area is subject to a limitation that is due to the maximum payload of the truck tray. With a given maximum payload of the truck tray, the maximum material volume that can be loaded during one loading cycle is defined by

$$Q_{lc,\max} = M_{pay} / \rho_{mat} .$$

The maximum material volume can then be translated into a maximum cross-sectional loading area

$$A_{tray,cr,\max} = Q_{lc,\max} / l_{lc} \qquad (2).$$

Inserting (2) into (1) and solving (1) for the truck speed produces a feedforward control law for the truck speed:

$$v_{Truck} = v_{SM}\left(1 + \frac{F_T \cdot F_B \cdot L \cdot \rho_{mat} \cdot l_{lc}}{M_{Pay}}\right).$$

The basic structure of a truck control unit is depicted in Fig. 4. The truck position and speed feedforward control unit 34 includes a feedforward control rule for the truck speed and for mapping the conveyor position onto the truck position. The truck position and speed feedforward control unit 34 includes measuring values 36, such as absolute conveyor positions and speeds, actual cutting depth and actual milling machine speed. Additional parameters 38 exist, such as the maximum payload of the truck, the loosening factor, the material density, the equivalent loading length of the truck tray, or the cutting width. 40 depicts the commanded speeds and positions (direction and amplitude), 42 depicts the truck control device, 44 depicts the control commands, speed commands, 46 depicts the truck, 48 depicts the absolute truck position, and 50 depicts the ATS/GPS.