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Process and device for the control of a motorized feed drive

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ABSTRACT

The invention consists of a process for the control of the motorized feed drive for the movable workpiece table of a machine tool, in particular the rolling carriage of a circular saw, in which the manual force that is applied by the operator in direction of the feed is sensed and converted to a corresponding measured value, from this a set value for the feed rate of the rolling carriage is created and from that is derived a control signal for the drive, and a device for the execution of the process with a longitudinally movable workpiece table, and a motorized drive for the movement that is connected to a control mechanism for the creation of a control signal for the speed (RPM) of the drive, where the control mechanism contains a manual force sensor and a control signal generator that is connected with/to it.

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COMPLETE SPECIFICATION

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INVENTION TITLE:

Process and device for the control of a motorized feed drive

The following statement is a full description of this invention, including the best method of performing it known to me/us:-

M090742 16 MAY97

The invention pertains to a process for the control of a motorized feed drive for a movable workpiece table of a machine tool, especially the rolling carriage of a circular saw, and a device for the execution of the process, with a workpiece table that with the aid of a motorized feed drive is longitudinally movable.

On many machine tools, e.g. also on circular saws, the workpiece feed is done by hand. In the example case, a workpiece to be sawed is laid down by the operator on the rolling carriage of the circular saw and subsequently pushed toward the circular saw blade in the direction of the cut. The rolling carriage serving as support for the workpiece is here moved along with it

(DE-PS 24 09 420). Therefore, the operator has to overcome in the advancement of the workpiece not only the cutting force, but also the friction existing between the rolling carriage and the machine frame. Furthermore, the rolling carriage must prior to each cutting process first be accelerated together with the workpiece, and after each cutting process be decelerated and subsequently retrieved. Especially with high-quality, i.e. warp-free (rigid against torsion) rolling carriages, alone the acceleration work for the acceleration and braking of the substantial mass of the rolling carriage is not inconsiderable. Added to this is the (mass) inertia of the workpiece. Consequently, where many cuts are made in quick succession, the operator must spend substantial energy for the repeated overcoming of the described forces. This results lastly in a faster exhaustion of the operator and in a loss of productivity.

For the overcoming of the forces opposing the workpiece feed, motor-driven rolling carriages are conceivable and are already in use for special application cases. For example, for the cutting of so-called postforming sheets a constant feed rate is partially applied, which can easiest be achieved with a motorized drive. A known design of such a drive consists of a hose that can be charged with compressed air, and on which a drive pulley (wheel) — attached to the rolling carriage — can roll off. If the air hose is blown up on one side with compressed air, the radially expanding air hose replaces the drive pulley and drives thereby the rolling carriage in the direction of the feed.

DE-OS 42 22 908 describes a feed hydraulics for sawing machines that adjusts the feed with a constant power corresponding to a set value (set point). Furthermore, electrical drives for a constant feed rate are known. (Periodical "PLASTverarbeiter" 10/1983, pages 1123, 1124).

A common disadvantage of the previously known motorized or hydraulic or pneumatic feed drives is their lack of flexibility. However, particularly the high flexibility of the machine tools that can be simply operated manually justifies the expensive employment of the personnel required for their operation.

Therefore, the object of this invention is the creation of a process for the control of a motorized feed drive, especially for a rolling carriage, that satisfies high requirements for the flexibility of the drive, especially regarding various feed rates, and the (creation of) a device for the execution of this process.

According to the invention, the reaching of this goal consists of a process with the characteristics of the generic term (meaning) of patent claim 1 in that the manual force applied by the operator in direction of the feed is sensed and converted into a corresponding measured value, a set value is created from it for

the feed rate of the rolling carriage, and from that a control signal is derived for the drive.

The required high flexibility of the feed drive results in the process according to the invention from using the manual force used by the operator for the influencing of the feed rate of the rolling carriage generated by a motor. A particular advantage of the solution provided by the invention is that it does not require a significant readaptation (retraining) by the operator, because the feed rate depends also in entirely manually operated machines, such as, e.g., circular saws, directly on the manual force applied by the operator in the direction of feed. The process allows simultaneously the reduction of the manual force, that needs to be applied by the operator, to a fraction of that which would be required if the operator would have to effect the feed entirely with his own power. According to the invention, the power of the operator is only required as input parameter for the control of the feed rate and thereby, in the end, independently of which forces have to be actually applied for the feed.

An advantageous variant of the inventive process is characterized by that additionally the cutting force is determined and considered in the generation of the set value for the feed rate. The consideration of the cutting force allows it, e.g., to reduce the feed rate, if the cutting force rises. The reduction of the feed rate may then be compensated for by an increased manual force of (applied by) the operator, so that the behavior of the motor-driven rolling carriage, controlled according to the invention, approximates then that of one manually driven. Furthermore, it is also possible to stop the feed in case of an extremely increasing cutting force, in order to prevent the standstill of the saw blade.

To prevent the start of the feed drive in case of very small manual forces, e.g., those unintentionally applied, the set value

of the feed rate is in a preferred variant set at zero as long as the applied manual force does not exceed a threshold value.

Preferably, the set value is created in dependence on the manual force in excess of the threshold value, so that it increases with increasing manual force and decreases with decreasing manual force. This corresponds to the behavior of a manually driven rolling carriage.

Furthermore, a process is preferred in which the set value is created such that it does not exceed an upper limit value, in order to not let the feed rate grow limitless and to prevent control fluctuations triggered by the rolling carriage temporarily escaping the operator so that the manual force of the operator diminishes, resulting in a stoppage of the rolling carriage, to be subsequently set in motion again by the operator.

To assure that the rolling carriage exhibits the expected behavior also in dependence on the cutting force, a process is preferred in which the set value is created in dependence on the cutting force such that it decreases with increasing cutting force and increases with decreasing cutting force. In this, the set value, (even if) just based on the influence of the cutting force alone, should preferably not fall below the value zero.

Preferably, upon initiation by the operator it should be possible to create also a negative set value for the feed rate so that the rolling carriage can also be moved backward by motor power. A preferred variant of the process according to the invention is characterized by a set value for the feed rate or a value of a speed control or RPM-control for the feed drive that is imposed as reference input value.

The inventive solution to the aforementioned task consists of a device with the characteristics of the generic term of patent

claim 10 in that a drive is connected with a control mechanism for the formation of a control signal for the speed of the drive, and the control mechanism contains a manual-force sensor and a control signal generator connected to it. The process according to the invention can be executed with the aid of such a device.

In order to allow also the consideration of the cutting force in the control of the feed drive, the control mechanism of a preferred form of execution of the device contains additionally a device for the determination of the actual cutting force, where the device is also connected to the control signal generator.

In order to facilitate a motorized backward movement of the rolling carriage, the control mechanism of the inventive device contains preferably an element for the presetting of a negative feed rate.

Furthermore, the device according to the invention is preferably equipped with a controller for the feed rate that is tied to the control signal generator. Such a device allows the use of a value for the feed rate that corresponds to the control signal

generator as reference input value for the control of the feed rate.

Preferably, the controller is part of the control mechanism or, in an alternative form of execution, part of the feed drive. The invention will now be explained in more detail with the aid of the illustrations (Fig.). It is shown in:

Fig. 1 a (circular) panel saw in perspective depiction for the elucidation of the size (value) relevant for the process;

Fig. 2 a panel saw in side view with a sensor unit attached to the rolling carriage;

Fig. 3 a block diagram of the drive control without consideration of the cutting force;

Fig. 4 a block diagram of the drive control with consideration of the cutting force; and

Fig. 5 a block diagram of the control signal generator.

The illustrations labelled a) to c) depict the sensor unit of Fig. 2 in several working positions in detail.

In the perspective depiction of a panel saw 10 in Fig. 1 a rolling carriage 12 is shown in its middle position, from where the rolling carriage 12 can be moved forward and/or backward until it reaches one of its two end positions. Furthermore, the direction of positive feed rate and positive feed force is indicated by an arrow. The value of the feed force is essentially determined by the rolling friction, the cutting force and — for accelerated rolling carriages — by the mass of the rolling carriage and the workpiece, and the acceleration. For an electric-motor-driven feed drive, the feed force is through the torque to be provided by the electric motor approximately proportional to the power consumption of the electric motor for the feed drive.

The already mentioned cutting force acts against the feed force. The peripheral cutting force to be overcome by a main saw motor driving the main circular saw blade must be differentiated from this cutting force (in direction of feed). The value of the peripheral cutting force is reflected in the power consumption of the main saw motor. The two identified cutting forces are connected and are essentially influenced by the material of the workpiece and its geometry, by the feed rate and the properties of the main circular saw blade, i.e. by the number of its teeth, by the shape of the teeth and their degree of dulling, and by the

projection of the saw blade beyond the plane defined by the surface of the rolling carriage .

In Fig. 2, a panel saw 10 with propelled and controlled rolling carriage 12 is depicted in side view. An external characteristic of the control is a sensor unit 16 that is attached to the surface of the rolling carriage 12 and is removable. The fastening occurs here by a tongue part that is held in a groove 18 (Fig. 1) and can be clamped in place there with a clamping lever 20. In the sawing of a workpiece 22, the sensor unit 16 serves simultaneously as guide for the workpiece laid on the surface of the rolling carriage.

The sensor unit 16 contains a lever 26, with the aid of which the feed drive can be controlled. The possible positions of the lever are clarified in the Fig. a) to c). Fig. a) depicts here a position for a positive feed rate as it is, e.g., desired in sawing. With the middle position of the lever, as depicted in Fig. b), the feed drive is turned off, and with the position depicted in Fig. c) the carriage return, i.e. a negative feed rate, is set. In Fig. a) is shown that the lever 26 in its

position depicted there functions together with a force sensor, with the aid of which the manual force of the operator can be measured to control the feed drive.

Additional essential elements of the panel saw 10 with controlled feed drive for the rolling carriage 12 are a control signal generator, a controller for the feed rate, and the drive for the feed. All known (types of) drives may be considered for the feed, such as, e.g., pneumatic or hydraulic drives or especially an electric-motor-drive. In the last-mentioned case, the rolling carriage 12 is driven by an electric motor through a gear (transmission). This case is used as basis for the following description of the control.

Based on the manual force applied by the operator to the lever 26 and determined with the aid of the force sensor, the control signal generator establishes a set value for the feed rate of the rolling carriage. Preferably, a measured value corresponding to the cutting force is also fed to the control signal generator, so that the cutting force can also be considered in the formation of the set value for the feed rate. A measured value corresponding to the cutting force can, e.g., due to the above described connection be derived from the power consumption of the drive motor for the main circular saw blade 14 or from the speed (RPM) change of the main saw shaft or from the power consumption of the feed motor for the rolling carriage 12. The set value for the feed rate established by the control signal generator is imposed as reference input value for the feed rate on a controller. Since a proportional connection exists between the feed rate and the speed variation of the driving electric motor that depends on the transmission gear ratio, the controller for the feed rate can, e.g., be a speed (RPM) controller for the driving electric motor. The speed controller can in known fashion be a component of the electric drive or, alternatively, be integrated in the control mechanism, especially in the control signal generator.

Known microprocessor controllers might be used as control signal generator.

How the set value for the feed rate (or for the RPM of the corresponding drive motor) is established in dependence on the two input values — on one hand the manual force to be applied by the operator and on the other hand by the cutting force — is described in the following. Below a threshold value for the manual force, the set value for the feed rate equals zero. In this manner is to be prevented that the rolling carriage is unintentionally already set in motion by a very small manual force. Above this threshold value, the set value for the feed rate increases with increasing manual force or decreases with

decreasing manual force. Furthermore, an upper value exists for the set value of the feed rate so that the latter cannot increase limitless, even with very high manual forces. In the simplest case, the connection between the manual force and the set value for the feed rate is above the manual force threshold value and below the limit value proportional for the feed rate. However, any other, preferably monotonous connection (relationship) between the two values is conceivable.

For the dependence of the set value on the cutting force applies similarly: With increasing cutting force, the set value for the feed rate decreases, but, alone on the basis of the manual force, maximally to the minimum value zero. Reversely, the set value increases with decreasing cutting force, but does here not exceed an upper limit value. Between the minimum value zero and the upper limit value, the dependence of the set value on the cutting force can be proportional. However, any other, preferably monotonous connection, is conceivable here.

If the lever 26 is in the center position depicted in Fig. b), the set value for the feed rate is set equal to zero. If the lever 26 is, however, set back for the carriage return (Fig. c)), a negative set value for the feed rate is created so that the rolling carriage runs backward. In order to simplify the control, a fixed value can be preset for the negative set value. However, it is equally possible to provide also for the back lever position (Fig. c)) a force sensor, with the aid of which the negative set value for the feed rate and, therefore, the backward (return) speed of the rolling carriage can be controlled.

Finally, also provided are limit switches with which the drive of the rolling carriage can be stopped before the rolling carriage 12 reaches its mechanically preset end position. The limit switches can here act directly on the drive or, alternatively, generate further input signals for the control signal generator.

The elements of a drive control without consideration of the cutting force are indicated in the block diagram depicted in Fig. 3. The drive control contains a manual-force sensor 30, with the aid of which the positive and negative manual force (F) of the operator is measured and converted into an electrical signal. Suitable manual force sensors are, e.g., piezoelectric pressure sensors that utilize the piezo effect, or DMS measuring bridges, which with the aid of strain gauges measure the (minimal) deformation of an essentially rigid sensor lever. Piezoelectric pressure sensors or DMS measuring bridges function practically pathless. Alternatively, the manual force sensor 30 can also contain a spring that in dependence on the manual force of (applied by) the operator is compressed or stretched. The deflection of the spring, corresponding to the manual force of (applied by) the operator, can then, e.g., by capacitive, magnetic, inductive or potentiometric path sensors, be converted to an electrical signal that corresponds to the manual force of (applied by) the operator.

The electrical output signal of the manual force sensor 30 is transmitted to a measuring amplifier 32, which converts and amplifies the measuring signal to a value that is suitable for digital processing and supplies the possibly required auxiliary energy for the manual force sensor 30.

The output signal of the measuring amplifier 32 is transmitted to the control signal generator 34, in which a filtering and signal adaptation (matching) of the measuring signal from measuring amplifier 32 takes place, and in this way as output signal a control signal for the rolling carriage drive is generated.

Interferences of the measuring signal are dampened and the measuring signal is smoothed out by the filtering of the measuring signal from measuring amplifier 32. In the signal adaptation (matching), the measuring signal from the measuring amplifier 32 is converted to the output signal such that the

characteristic curve of the sensor of the manual-force sensor 30 is adapted to any characteristic function curve, optimized to the application. For this, sensible threshold values and limit values are considered. Through utilization of a microcomputer, the function for the signal adaptation, and the consideration of threshold values and limit values, can within wide boundaries be adapted and optimized for obtaining the desired behavior of the signal adaptation (matching). A progressively acting adaptation achieves, e.g., that the support of the feed motion of the rolling carriage 12 by the drive does with increasing manual force increase superproportionally. This has the result that the support is minimal for low manual forces and does not diminish the operator's feel. A similar effect can also be obtained by that the support, proportionally to the manual force, does become effective only from a certain threshold value on.

The manual-force sensor 30 and the measuring amplifier 32 are part of the sensor unit 16 and, together with the control signal generator 34, constitute the control mechanism 36. The output signal of the control signal generator 34 is simultaneously the output signal of the control mechanism 36, i.e. the control signal for the drive of the rolling carriage 12.

In the example of execution depicted in Fig. 3, the control signal is directed to a control unit 38 for the drive 40 of the rolling carriage 12, which consists of a controller 42 and a power output (end) stage 44 for the activation of the motor of drive 40. The control signal from the control mechanism 36 serves as reference input value or set value for the control unit 38 of the drive 40.

In a variant of the control of the drive for the rolling carriage 12 the cutting force is considered, as already described above. The block diagram of a corresponding drive control is depicted in Fig. 4. The manual-force sensor 30 and the measuring amplifier 32

correspond to those previously described. Also, the control unit 38 with controller 42 and the power output stage 44 does not differ from that previously described. It controls the drive motor 50, which is connected through a gear (transmission) 52 with the rolling carriage 12. The drive motor 50 and the gear (transmission) 52 are here components of the drive 40. The gear (transmission) 52 is advantageously equipped with a detachable coupler (clutch), so that the rolling carriage 12 can be moved by hand, independently of the drive motor 50.

As already described above, the cutting force can indirectly be determined by the measuring of the motor power (consumption) of the motor 54 driving the main saw blade 14. Alternatively, it is also possible to measure the torsion of the drive shaft 56 of the main saw blade 14 with the aid of strain gauges, and such determine the cutting force. For the determination of the cutting force, the drive control depicted in Fig. 4 contains a cutting force sensor 60, whose output signal is by a second measuring amplifier 62 converted and amplified to a value that is suitable for digital processing. The second measuring amplifier 62 supplies, if need be, a required auxiliary energy for the cutting

force sensor 60. The measuring signal for the cutting force exiting the measuring amplifier 62 is fed to the control signal generator 34'.

The control signal generator 34' contains essentially three function blocks: A first function block 70 for the filtering and adaptation of the manual force measuring signal from the measuring amplifier 32, and a second function block 72 for the filtering and adaptation of the measuring signal for the cutting force arriving from the second measuring amplifier 62. The output signals from the two function blocks 70 and 72 are fed to a mixer 74.

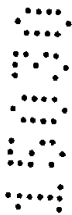
The first function block 70 for the filtering and adaptation of the manual force measuring signal has already been described above in connection with the control signal generator 34 depicted in Fig. 3. The second function block 72 for the filtering and adaptation of the cutting force measuring signal does function similar to the first function block 70, i.e. a signal filter dampens first interferences and does smoothen the measuring signal. In the signal adaptation (matching), the characteristic curve of the cutting force sensor 60 is adapted to the desired characteristic function curve. Additionally, possible threshold values and limit values are considered. The adaptation of the characteristic curve of the cutting force sensor occurs such that a rising cutting force results in a reduction of support of the feed motion of the rolling carriage by the drive.

In the mixer 74, the function values derived from the two actuating variables — manual force and cutting force — are brought together and are used for the creation of a set value (reference input value) for the control unit 38. The algorithm for this is realized in the mixer 74.

- In Fig. 5, the control signal generator 34' is detailed (broken down) further. Recognizable are a first block 80 for the adaptation of the manual force measuring signal and a block 82 for the adaptation of the cutting force measuring signal.
- Examples of suitable functions for the signal adaptation (matching) are graphically depicted in the two blocks 80 and 82.
- The manual force measuring signal FH is in the course of the signal adaptation (matching) converted to the manual force function value @FH, and the cutting force measuring signal FS (is converted) to the cutting force function value @FS. The adaptation is here dependent on pre-settable function parameters.
- The two function values @FH and @FS are subsequently weighted at (in) the blocks 84 and 86 in dependence on pre-settable

evaluation parameters, and in an algorithm block 88 balanced against each other. The algorithm used in algorithm block 88 can here be preset. The blocks 84, 86 and 88 are components of the mixer 74 and are, like the blocks 80 and 82, realized in the form of a microcomputer that forms the control signal generator 34', so that the individual blocks 80 to 88 correspond to program modules of a program that needs to be processed by the microcomputer.

As already described above, a behavior of the rolling carriage can be obtained with the aid of the described process and the described device, as it is expected by the operator based on his experience. This allows an intuitive control of the rolling carriage drive and prevents shop accidents due to unforeseen behavior of the rolling carriage. Furthermore, the operator is substantially relieved in regard to the force required for the rolling carriage drive.



THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Process for the control of a motorized feed drive for a movable workpiece table of a machine tool, especially of a rolling carriage of a circular saw, characterized by that the manual force exerted by the operator in direction of feed is sensed and converted to a corresponding measured value, a set value for the feed rate of the rolling carriage is created from it and a control signal for the drive is derived from that.
2. Process according to claim 1, characterized by that in addition the cutting force is determined and considered in the formation of the set value for the feed rate.
3. Process according to one of the claims 1 or 2, characterized by that the set value for the feed rate is set at zero, as long as the applied manual force does not exceed a threshold value.
4. Process according to one of the claims 1 to 3, characterized by that the set value in dependence on the manual force is created such that it increases with increasing manual force and decreases with decreasing manual force.
5. Process according to one of the claims 1 to 4, characterized by that the set value does not exceed an upper limit value.

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6. Process according to one of the claims 2 to 5, characterized by that the set value in dependence on the cutting force is created such that it decreases with increasing cutting force and increases with decreasing cutting force.

7. Process according to claim 6, characterized by that the set value in dependence on the cutting force is created such that it, based only on the influence of the cutting force, does not fall below the value zero.

8. Process according to one of the claims 1 to 7, characterized by that in response to a return run signal, preset by the operator, a negative set value for the feed rate is established.

9. Process according to one of the claims 1 to 8, characterized by that the set value for the feed rate, or a value of a speed or RPM control proportional to it, is as reference input value impressed on the feed drive.

10. Device for the execution of the process according to one of the claims 1 to 9, with a workpiece table that can be moved longitudinally with the aid of a motorized feed drive, especially a rolling carriage of a circular saw, characterized by that a drive is connected with a control mechanism for the creation of a control signal for the speed variation of the drive, and the control mechanism contains a manual force sensor and a control signal generator connected to/with it.

11. Device according to claim 10, characterized by that the manual-force sensor is a component of a sensor unit, which additionally is equipped with a measuring amplifier and is a component of the control mechanism.

12. Device according to claim 10 or 11, characterized by that the control mechanism additionally contains at least one



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device for the determination of the actual cutting force, and the device is also connected with/to the control signal generator.

5 13. Device according to one of the claims 10 to 12, characterized by that the control mechanism contains an element for the pre-setting of a negative feed rate.

14. Device according to one of the claims 10 to 13,
10 characterized by that it contains a controller for the feed rate that is connected to/with the control signal generator.

15. Device according to claim 14, characterized by that the controller is part of the control mechanism.

15 16. Device according to claim 14, characterized by that the controller is part of the feed drive.

17. A process for the control of a motorized feed
20 substantially as hereinbefore described with reference to the drawings and/or Examples.

18. A device for the control of a motorized feed
substantially as hereinbefore described with reference to the
25 drawings and/or Examples.

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DATED this 1st day of July, 1999

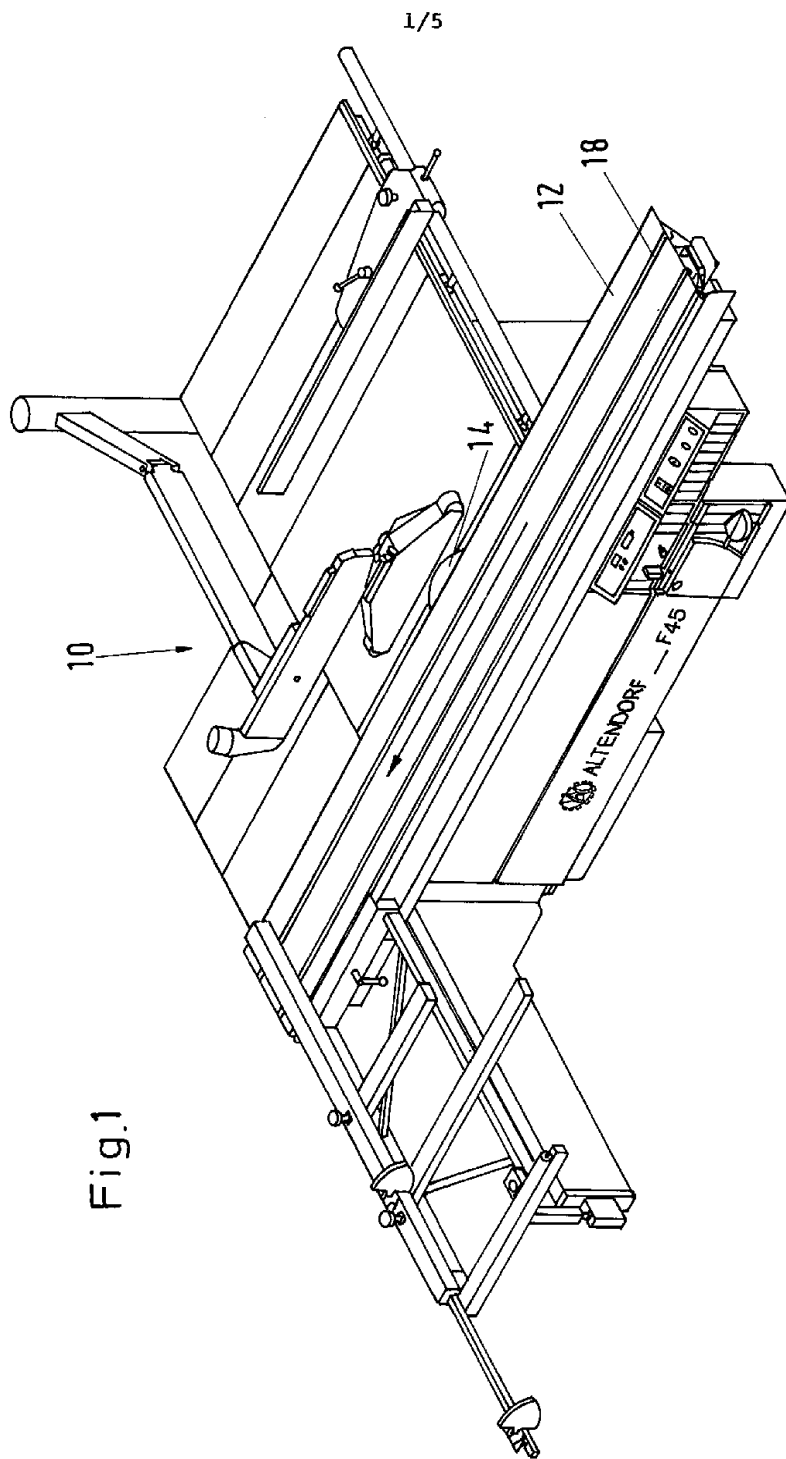
35 WILHELM ALTENDORF GMBH & CO. KG

By its Patent Attorneys

DAVIES COLLISON CAVE

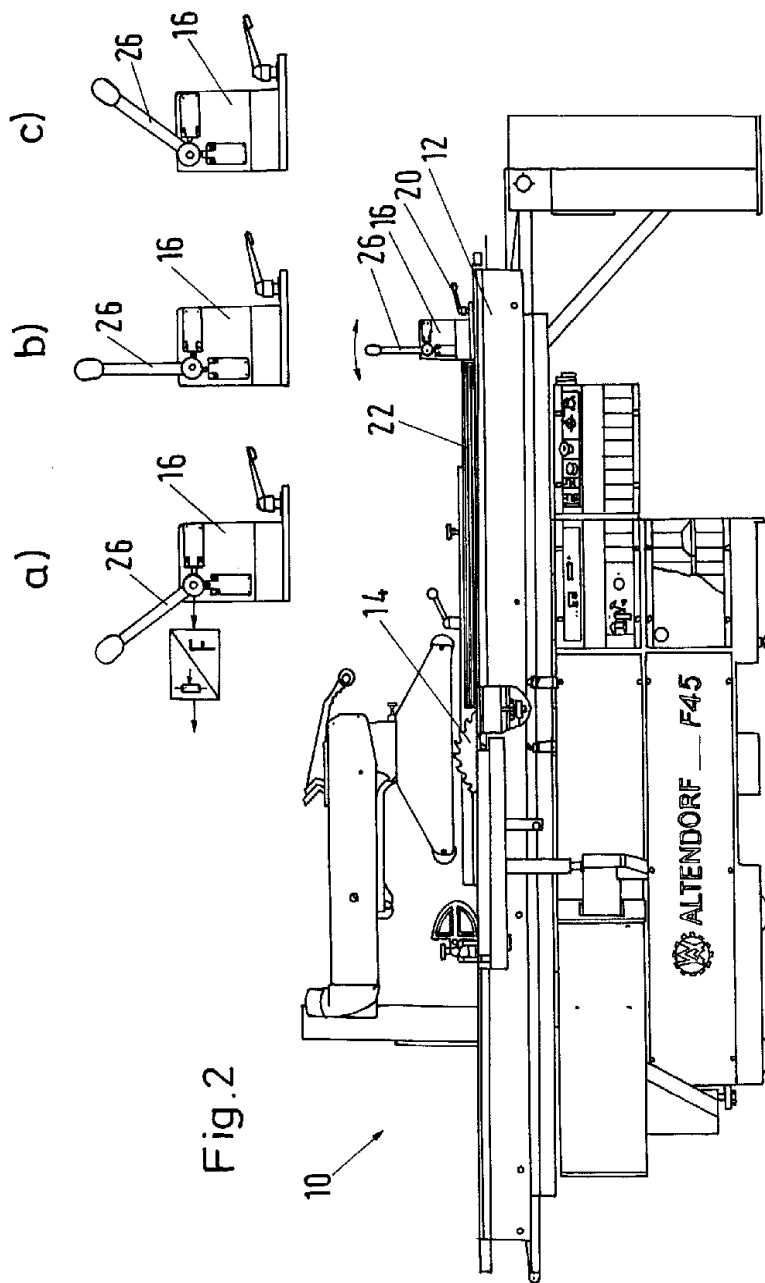


Fig.1



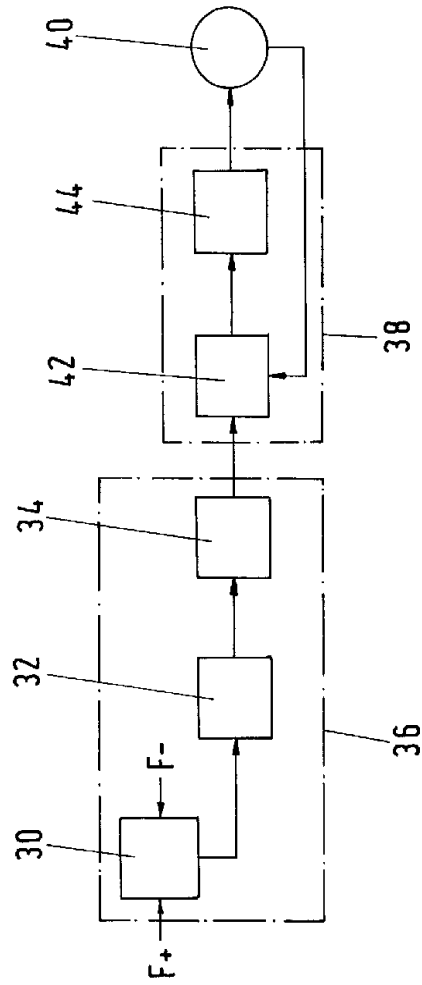
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Fig.2



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Fig.3



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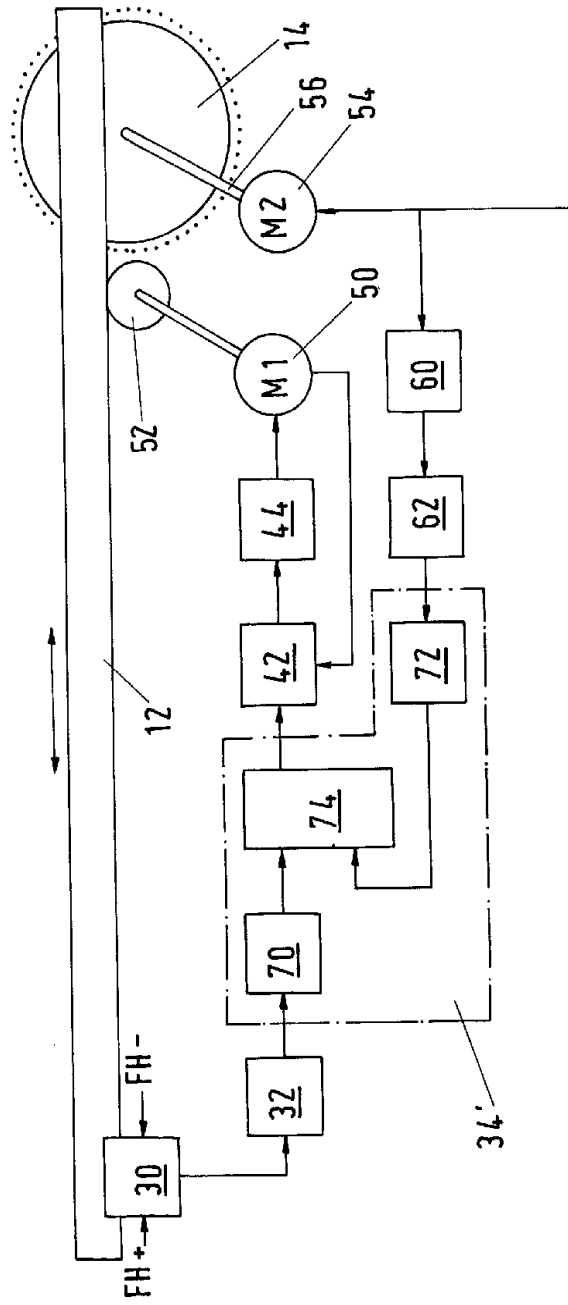


Fig.4

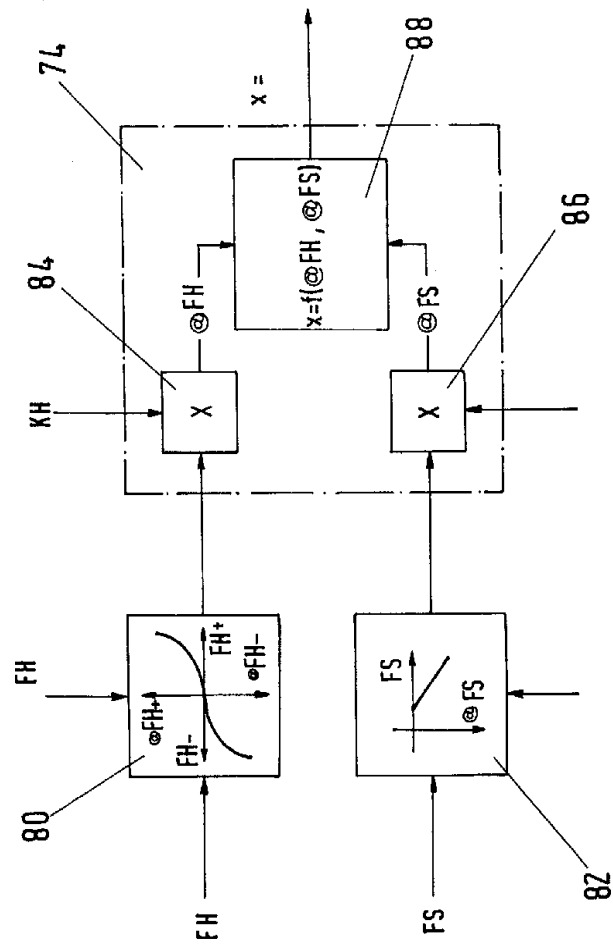


Fig.5