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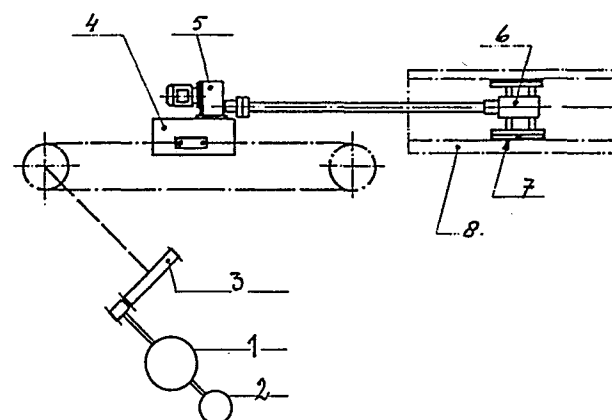
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⑤④ **Horizontal honing machine.**

⑤⑦ A horizontal honing machine for large and small stroke lengths comprises a frame with a guiding bar and a linearly driven sled (4) with a motor (5) for the rotating motion of the honing head (6). The drive of the sled (4) is moved by a direct current motor (1) with servo control and transistor adjustment, whereby the speed and point of reversal of the motion of the sled (4) in the stroke are almost independent from the load of the honing head (6) and are accurately repeating.



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Horizontal Honing Machine.

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The invention relates to a horizontal honing machine for working up cylindrical bores, for which a very good quality of the worked surface and a high accuracy of measure are required, such as for example are required for cylinder walls of hydraulic and pneumatic installations.

5 The honing activity is effected by means of strips of grinding material, placed upon the circumference of a dilatatable bearer (honing head), which is moved simultaneously axially and rotationally by a sled in the bore whereby a spiral grinding process in both directions to and fro is taking place.

10 Thus the polishing grooves are formed in a crosswise manner.

In order to obtain an exactly parallel bore, the reversal motion of the axial drive is most critical.

Any slackening of speed or stagnation of the axial motion with regard to the continuously rotating motion will cause a local increase of grinding
15 off more material, such that the bore will become locally wider.

Horizontal honing machines with a sled for large stroke lengths (of 1000 mm up to 10.000 mm) are known, wherein the axial drive of the sled is carried out either hydraulically or electromechanically.

The disadvantage of a hydraulic drive of the sled is the fact that this re-
20 quires an excess of installed power, in order to be enabled to deliver the power peak for fast reversal.

Consequently, the output efficiency of the hydraulic drive is poor.

The disadvantages of the known electromechanical drives of the sled are the changing-over time, which is too long, and the inertia momentum of the
25 moving accessories, resulting in a reversal motion, which is too slow.

Both systems show a less accurate reversal point mainly at high speed, which means that the honing process cannot be carried out with the optimal

speed.

To a major extent this applies to the honing of blind bores.

Therefore a solution was investigated to remove these advantages.

A thorough research resulted in a machine, with which the above disadvantages are obviated to a considerable extent.

The horizontal honing machine with driven sled for large and small stroke lengths, comprising a frame with a guiding bar and with a linearly driven sled with a motor for the rotatory motion of the honing head is characterized according to the subject invention, in that the drive of said sled is moved by a direct current motor with servo control and solidstate transistor adjustment, whereby the speed and the reversal point of the motion of the sled in the stroke are almost independent from the load and are accurately repeating.

For said controlling three systems are appropriate.

The controlling can be effected by means of a threephase thyristor converter.

With this a three phase alternating tension is rectified, whereby the pulsefrequency ranges from 150-300 Hz.

The controlling can also be effected by a direct current transistor regulator in combination with a brushless synchronic motor having permanent magnets at the rotor and coils at the stator.

The current fed to the coils is electronically commuted.

The preferred embodiment is a transistor with pulse width modulation.

With this device the alternating tension is first rectified and subsequently equably chopped.

The tension at the rotor collector connections is influenced by varying the width of the pulses.

The frequency of the pulses ranges from about 1000 to 10.000 Hz.

With this device a motor with permanent magnet and a built-in tachogenerator is used.

In this manner the driving power is provided by a closed circuit for speed regulation having short reaction periods.

Thereby the set speed and the reversal of the motion are independent from load and very accurate.

The switching over of the servo control can be effected by a sequence of signals which are introduced according to a preset programme for continuous production tasks.

The axial speed during the honing process ranges between about 10 and 40 m/min.

The power drive used in accordance with the invention renders the possibility to retard the sled with the honing head at an axial speed of 30 m/min, to effect the reversal without perceptible standstill and to bring it to the set speed in the reverse direction again within 1/3 second.

- 5 A second advantage of the drive according to the invention is the feature that with an equally remaining adjustment of the speed of the axial motion a very accurately set point of reversal of the sled is obtained, which is practically independent from the axial load and which will be repeated continually with exactness.
- 10 This is of great importance in practice, for example for the honing of bores with blind bottoms.

It appeared to be possible to make use of the optimal speed of the sled also for the honing of blind bores and in this respect to hone even at a distance of 2 to 3 mm only from the bottom.

- 15 The power installed for the drive is 15 kW at the utmost.
- The drive is delivering only the power which is to be used at any moment. During the reversal the peak charge to drag and to start running up is consumed and during the further uniform speed of the stroke only the power for the motion of the honing head through the piece of work is
- 20 consumed.

Therefore the total efficiency of the electrical drive is becoming higher than that of conventional systems.

- The drive with control according to the invention enables to make the reversal of the sled accurately also in case of high axial speed (40m/min),
- 25 so that during the honing of blind bores the optimal speed can be applied. The servomotor has a low inertia momentum and it can endure the high strengths of current during short periods which are necessary for the start of running up and for the dragging operations.

- Because of these high speeds obtainable with the said drive the machine is
- 30 also appropriate for honing by means of novel cutting materials, such as boron nitride (The use of boron nitride is described i.a. in "Werkstatt und Betrieb", Ed. Hanser, 116, (1983), nr. 6, p. 399 a.f.).

The invention is further elucidated on the basis of the enclosed drawings 1 and 2.

- 35 Figure 1 shows in part a schematic cross|section of the installation according to the invention.

Therein (1) is the servomotor, (2) a tachogenerator, (3) a reductor, (4) the sled, (5) the motor for the rotatory drive, (6) the honing head with the honing stone (7) in the piece of work (8).

Figure 2 shows schematically the electrical control circuit of the installation.

(1) is the servomotor, (2) the tachogenerator, (9) a potentiometer, (10) a Reed-relay, (11) a gradient generator, (12) a servo amplifier, (13) an
5 internal current circuit.

The servomotor (1) has low inertia momentum and it can endure high currents during short periods, which are necessary for start and dragging.

The tachogenerator (2) is mounted upon the shaft of the servomotor (1).

The reductor (3) has a low inertia momentum too and its construction is
10 with inconsiderable play.

At the console for the operator of the device a potentiometer (9) is mounted, which delivers a tension linearly proportional with the angle of adjustment.

This adjusted value is switched over to the servo amplifier (12) by means
15 of the Reed-relay (10) with mercury contacts, which have a switching delay of about 2 milliseconds.

The signal of the adjusted value is fed into the gradient generator (11), which transforms a non-linear signal into a value of tension including or declining linearly with time, and thus provides for uniformly accelerating
20 start and uniformly retarded dragging respectively of the motor (1).

The tachogenerator (2) at the shaft of the motor (1) delivers a tension increasing linearly with speed of rotation and the polarity of which depends from the direction of rotation.

This signal of the tachogenerator pursuant to the gradient generator (11) is
25 compared with the adjusted value.

The servoamplifier (12) controls the current and the tension for the motor (1) in such a manner, that the measured signal of the tachogenerator is consistent with the adjusted value, whereby the control circuit for the rate of speed is closed.

30 If the axial speed of the motor (1) would alter as a consequence of the forces of honing and of mass, the system will instantaneously react and deliver a tension and a rotatory moment appropriate to reduce the speed into the previous situation.

An internal current circuit (13) is added to provide for a feed-back signal in order to obtain a precise adjustment of the rotatory moment.
35

The drive renders the possibility to enable the sled and all the accessories connected with it as well as the honing equipment to move to and fro, with a speed of 40 m/min.

The sled shall stop in it at the end of the stroke flexibly and accurately

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reaccelerate without noticeable standstill.

The stroke depth is about 10.000 mm.

The displacement length is about 13.000 mm.

With a speed in the stroke of 30 m/min which occurs quite often, each the
5 dragging and the accelerating distances should not be in excess of 40 mm.

The following calculation demonstrates the favourable results with sled
speeds up to 40 m/min.

Calculations for the frequently used speed of 30 m/min and with a dragging
distance of 40 mm are as follows:

10	Weight of the sled, rotating drive included, total:	178 kg
	Weight of driving chain:	59 kg
	Weight of cable leads and cables:	57 kg
	Honing equipment, up to:	<u>30 kg</u>
	Mass in motion to and fro: total	324 kg.

15 Efficiency of the sled guidance:

ball bearings($\eta = 90\%$)

Reductor:

retardation factor $i = 11.0$

mass inertia momentum $J_1 = 1.971 \cdot 10^{-4} \text{ Kgm}^2$

20 yield $\eta = 92\%$

divider circle of chain wheel dia. = 0.152 m.

Permanent magnet motor:

(pos. 1, with tachogenerator)

mass inertia momentum: $I_2 = 0.026 \text{ kgm}^2$

25 strength of current taken up = 1.22 Amp/Nm

current peak, max. = 140 Amp

max. continuous torque = 30 Nm.

Servo amplifier:

strength of current, admissible of short duration = 50 Amp.

30 strength of current continually chargeable (at 100 V

tension at motor) = 32 Amp.

Axial honing force, max.: $F_a = \text{about } 1500 \text{ N}$

The load occurring with the servomotor for running up:

The running up and dragging respectively of the sled is uniformly accele-
35 rated and uniformly retarded respectively.

With a sled speed adjusted at 30 m/min the starting distance and the drag-
ging distance are both 40 mm.

$s = 40 \text{ mm} = 0.040 \text{ m.}$

$$V = 30 \text{ m/min} = 0.50 \text{ m/sec}$$

$$S = 0.5 \cdot V \cdot t \quad \text{with uniformly accelerated running.}$$

$$t = \frac{S}{0.5 \cdot V} = \frac{0.04}{0.5 \cdot 0.5} = 0.16 \text{ sec.}$$

speed of rotation of the servo motor:

$$5 \quad n = \frac{V}{\pi \cdot \text{circle dia.}} \cdot i = \frac{0.50}{\pi \cdot 0.152} \cdot 11$$

$$= 11.518 \text{ r/sec.}$$

Angle acceleration of the servo motor:

$$\Sigma = 2\pi \cdot n \cdot \frac{1}{t} = 2\pi \cdot 11.518 \cdot \frac{1}{0.16}$$

$$= 452.3 \text{ rad/sec}^2$$

10 Mass inertia momentum of mass moving to and fro:

$$J_3 = m \cdot r^2 = 324 \cdot \left(\frac{0.152}{2} \right)^2 = 1.871 \text{ kgm}^2$$

J_3 calculated relating to the speed of rotation of motor:

$$J_{3 \text{ red}} = \frac{J_3}{i^2} = \frac{1.871}{11^2} = 0.01547 \text{ kgm}^2$$

Total of mass inertia momentum:

$$15 \quad J = J_1 + J_2 + J_{3 \text{ red}}$$

$$J = 1.971 \cdot 10^{-4} + 0.026 + 0.01547 = 0.04166 \text{ kgm}^2$$

Motor torque required for start with honing head loadless:

$$M_{\text{dyn}} = \frac{J \cdot \Sigma}{\eta_{\text{sled}} \cdot \eta_{\text{reductor}}} = \frac{0.04166 \cdot 452.3}{0.90 \cdot 0.92} = 22.76 \text{ Nm}$$

$$20 \quad \text{Dynamic start current } J_{\text{dyn}} = 22.76 \cdot 1.22 = 27.77 \text{ Amp.}$$

Motor torque required for maximal axial honing force:

$$M_{\text{stat}} = \frac{F_a \cdot r}{i \cdot \eta_{\text{sled}} \cdot \eta_{\text{reductor}}} = \frac{1500 \cdot \frac{0.152}{2}}{11 \cdot 0.90 \cdot 0.92} = 12.52 \text{ Nm}$$

Static motor current:

$$i_{stat} = 12.52 \cdot 1.22 = 15.27 \text{ Amp.}$$

Maximal load of the servo motor:

Uniformly accelerated starting of the honing machine with stroke depth of 10.000 mm, under full load of honing head, up to 30 m/min in 0.16 sec:

$$M_{max} = M_{dyn} + M_{stat}$$

$$= 22.76 + 12.52 = 35.28 \text{ Nm}$$

$$i_{max} = i_{dyn} + i_{stat}$$

$$= 27.77 + 15.27 = 43.04 \text{ Amp.}$$

The maximum torque is hardly higher than the continuously admissible torque of 30 Nm.

The maximum motor current is considerably lower than the admissible peak of 140 Amp.

Thus the servo motor has sufficient reserve strength.

At a sled speed of 40 m/min the same maximum charge takes place but it is lasting only $\frac{40}{30} \cdot 0.16 = 0.21$ sec.

Servo amplifier:

The short duration starting current of 43.04 Amp is amply lower than the tolerable value of 50 Amp.

The current strength of 15.27 Amp. required during the uniform speed of stroke is about 50% of the current strength of 32 Amp., which is continuously tolerable.

The servo-amplifier is therefore sufficiently ample of construction.

Accuracy of control of the servo drive system:

The influence of the mass inertia of the servo motor is considerably higher than that of the sled plus the rotating drive plus the honing equipment. The load effected by the honing force is relatively low.

Consequently this drive renders an accurate reversal which is almost independent from honing force.

Experiments have been performed in order to determine the accuracy of reversal with the horizontal honing machine according to the invention with a stroke depth of 2500 mm:

Drive of the sled : permanent magnet motor with servo-amplifier

Piece of work: Tube ϕ 195. ϕ 215, length 960 mm, Steel 35.

Honing head: ANR 250 type with support cage.
Honing stones: 4 only, W 47 A 45
Honing oil: MAN 841.5 type with about 15 l/min.
Circumferential speed: $V_{rot} = 52$ m/min

- 5 Speed in the stroke: 30 and 40 m/min;
see tables.

The results of the experiments are reported in the tables I and II.

Measurements have been made with gauge with 0.01 mm divided scale and 5 mm stroke depth.

- 10 The values of results of runs 2,5,6,7 and 8 have been rounded off to 0.05 mm, the values of runs 9,10 and 11 have been rounded off to 0.1 mm. Measurements have been made under different load conditions and at two successive days in order to examine the influences of prolonged standstill periods and of cooling down.

- 15 From the first run until after run 8 no adjustment whatsoever of the machine had been altered.

For the augmentation of the speed in the stroke from 30 to 40 m/min the gauge has been displaced because then the running out distance of the sled was longer.

- 20 With a speed in the stroke of 30 m/min the measured spread of the point of reversal was 2.21 mm at the highest, while the load of the honing force was varying from 0 to 1.02 kW.

With a stroke speed of 30 m/min and the same load the measured spread was 0.7 mm.

- 25 When the stroke speed was augmented to 40 m/min, the spread values were the same as with a speed of 30 m/min.

The augmentation of the rotational load is resulting from the increase of the speed in the stroke.

From the experimental runs and the measured values it appears that with

- 30 the machine according to the invention an important progress with respect to the known systems of construction has been attained.

T A B L E I:

Date:	6_9_1983			7_9_1983					7_9_1983		
Time:	17.00	17.10	17.20	08.30	08.40	08.50	09.00	09.10	15.25	15.35	15.45
Run:	1	2	3	4	5	6	7	8	9	10	11
Stroke speed (m/min):	30	30	30	30	30	30	30	30	40	40	40
Rotational net load											
of honing head, (Kw):	0	0,86 1,02	0	0	1,02	0,77	0,51	0	0	0,85	1,15
Distance gauge max. (mm)	1,97	3,20	1,80	2,00	3,60	3,10	2,60	1,95	2,7	3,3	3,6

Distance gauge min. (mm)	1,59	2,50	1,39	1,64	2,85	2,75	2,25	1,60	2,3	2,6	2,9
Spread ,mm:	0,38	0,70	0,41	0,36	0,75	0,35	0,35	0,35	0,4	0,7	0,7
Arithmetle mean (mm):	1,79	2,85	1,57	1,81	3,21	2,87	2,46	1,75	2,48	2,89	3,22
Deviation from 1 and 9:	0,00	+1,6	-0,22	+0,02	+1,42	+1,08	+0,67	-0,04	0,00	+0,41	+0,74

5 Spread maximum, at 30 and

40 mm/min resp. (mm):

$$3,60 - 1,39 = 2,21$$

$$3,6 - 2,3 = 1,3$$

T A B L E II:

Date:

Time:

10 Run:

Stroke speed (m/min):

rotat. net load of honing-

head (KW):

Gauge values (mm):

6-9-1983			7-9-1983					7-9-1983		
17.00	17.10	17.20	08.30	08.40	08.50	09.00	09.10	15.25	15.35	15.45
1	2	3	4	5	6	7	8	9	10	11
30	30	30	30	30	30	30	30	40	40	40
0	0,86 1,02	0	0	1,02	0,77	0,51	0	0	0,85	1,15
1,81	2,55	1,65	1,75	3,40	2,80	2,45	1,60	2,4	3,3	3,1
1,70	2,50	1,77	1,77	3,00	2,85	2,40	1,80	2,3	3,1	3,3
1,65	2,95	1,55	1,75	3,10	2,75	2,60	1,85	2,3	3,2	2,9
1,59	2,50	1,60	1,69	3,20	2,85	2,60	1,85	2,4	2,8	3,6
1,64	2,85	1,54	1,96	3,60	3,00	2,60	1,90	2,6	3,0	3,4
1,66	2,90	1,56	1,74	3,25	2,80	2,35	1,65	2,7	2,7	3,1
1,93	2,80	1,73	1,71	3,25	2,95	2,30	1,90	2,5	2,6	3,5
1,93	2,90	1,80	1,68	3,35	2,75	2,55	1,95	2,3	2,7	3,4
1,78	2,55	1,56	1,92	3,20	3,10	2,50	1,60	2,7	2,8	3,0
1,95	3,00	1,72	1,83	3,45	2,75	2,40	1,80	2,7	3,2	3,5
1,72	2,60	1,79	1,67	3,15	2,80	2,55	1,60	2,4	2,9	3,3
1,79	3,00	1,55	1,90	3,35	2,90	2,60	1,60	2,3	2,7	3,1
1,96	3,20	1,75	1,96	3,10	2,80	2,25	1,70	2,6	2,6	2,9
1,87	3,15	1,53	1,94	2,90	3,00	2,30	1,90	2,3	3,1	3,3
1,81	3,00	1,52	1,89	2,85	2,95	2,50	1,65	2,7	2,7	2,9
1,85	3,20	1,52	1,63							
1,66	2,95	1,69	1,76							
1,97	2,95	1,47	1,71							
1,73	3,15	1,40	1,92							
1,64	2,80	1,51	1,88							
1,77	2,70	1,42	1,86							
1,90	3,00	1,62	1,91							
1,94	2,95	1,60	1,88							
1,69	2,60	1,60	1,93							
1,73	2,70	1,64	1,87							
1,64	2,80	1,39	2,00							

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Table II (continued):

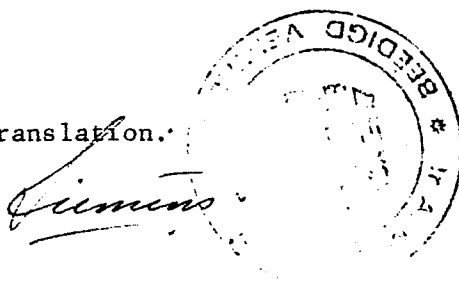
1,69	2,90	1,61	1,97					
1,86	3,05	1,45	1,86					
1,92	2,90	1,64	1,69					
1,88	3,05	1,41	1,64					
1,67	2,70	1,35	1,75					
1,86	2,55	1,60	1,93					
1,86	2,85	1,62	1,78					
1,79	2,70	1,41	1,72					

Claims:

1. Horizontal honing machine for large and small stroke lengths, comprising a frame with a guiding bar and a linearly driven sled with a motor for the rotating motion of the honing head, characterized in that the drive of the sled is moved by a direct current motor with servo control and transistor adjustment, whereby the speed and the point of reversal of the motion of the sled in the stroke are almost independent from the load of the honing head and are accurately repeating.
2. Honing machine according to claim 1, characterized in that the servo control comprises a three phase thyristor regulator.
3. Honing machine according to claim 1, characterized in that the servo control comprises a direct current transistor regulator with electronic commutation, whereby a brushless synchrone motor with permanent magnets at the rotor and with windings at the stator is used.
4. Honing machine according to claim 1, characterized in that the servo control comprises a pulse-width-modulated transistor regulator.
5. Honing machine according to one of the claims 1 through 4, characterized in that the switching over of the servo control is effected by a sequence of signals, which is fed into in accordance with a programme for continuous production tasks.
6. Honing machine, comprising a linearly driven sled (4) with a motor (5) for the rotating motion of the honing head (6) with honing stone (7), characterized in that the motion of the drive of the sled (4) is effected by a direct current motor (1) with servo control, tachogenerator (2) and reductor (3), whereby the electrical regulation comprises a potentiometer (9), which delivers a tension linearly proportional to the adjustment angle, a Reed-relay (10) and a servo-amplifier (12) with gradient generator (11) and internal current circuit (13) for accurate regulation of the rotational momentum.
7. A method for the horizontal honing of bores, characterized in that a machine according to one of the claims 1 through 6 is used.

8. A product obtained by the use of means according to the method according to claim 7.

Certified Translation.



(Drawings)

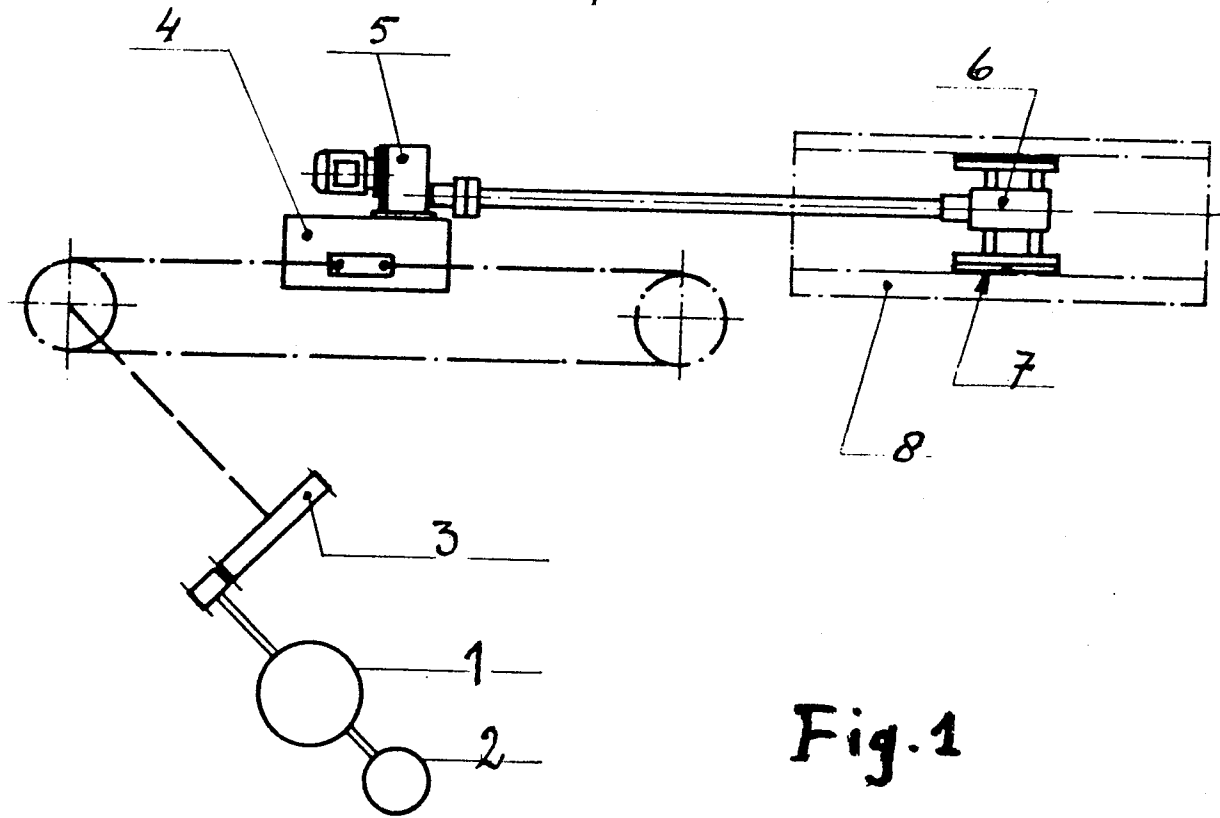


Fig. 1

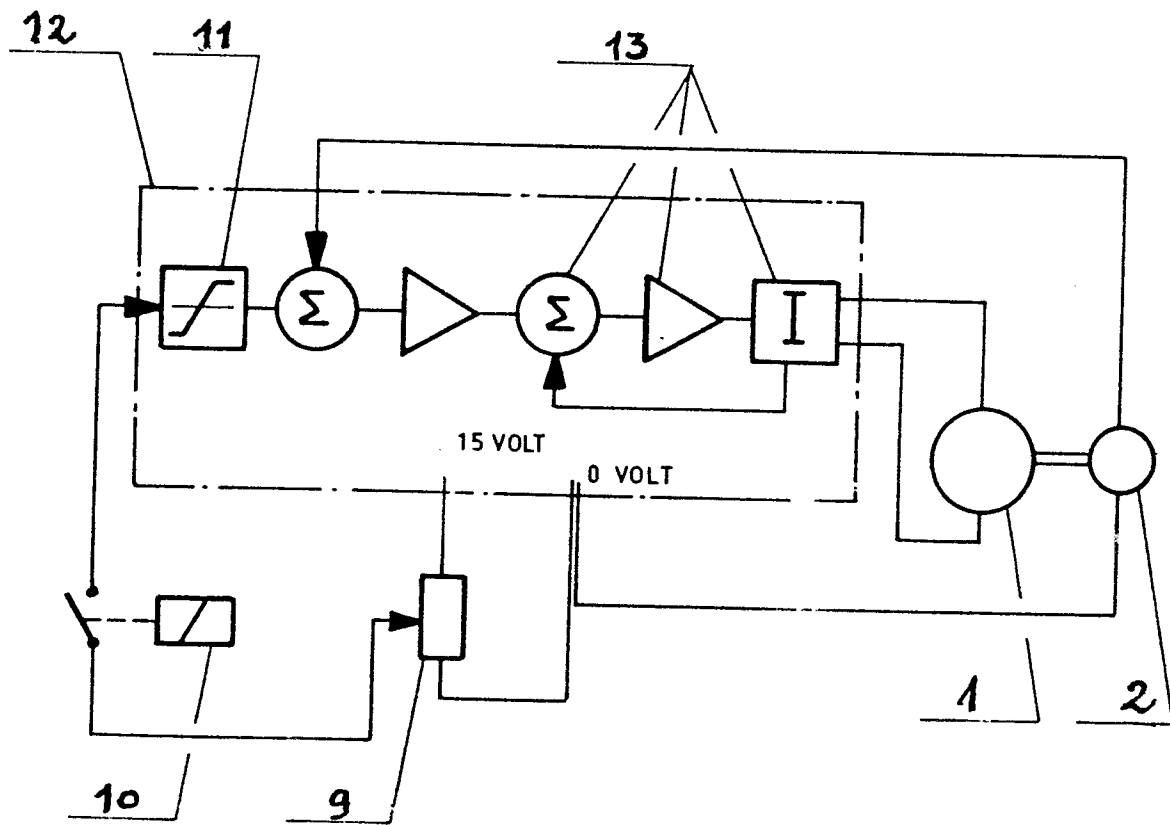


Fig. 2



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Y	DE-B-2 347 780 (MASCHINENFABRIK GEHRING) * Claim 1; column 3, lines 43-54; figure 1 *	1,6	B 24 B 33/02
Y	--- ELEKTRISCHE AUSTRÜSTUNG, vol. 15, no. 5, October 1974, Würzburg K. BRUCHMANN "Dynamische Serroantriebe für Arbeitsmaschinen", pages 9-14 * Page 9; figure 1; pages 12-14 *	1,6	
A	--- ELEKTRISCHE AUSTRÜSTUNG	2-5	
A	--- TECHNICA, no. 6, 1977, Basel M. DELATTRE et al. "Gleichstrom-Servomotoren für Vorschubsysteme", pages 321-326 * Page 326; figure 14 *	2	
A	--- US-A-3 618 268 (SUNNEN) * Column 7, line 71 - column 8, line 25; figure 10 *	1	
A	--- US-A-3 237 350 (ESTABROOK) * Figures 1, 13 *	1	
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 21-05-1984	Examiner MARTIN A E W
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			