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(54) **METHOD OF CONTROLLING THE COURSE OF THE LIFTING FUNCTIONS OF THE MAIN MECHANISMS OF A WEAVING MACHINE**

(57) The invention relates to a method of controlling the course of lifting functions of the main mechanisms of a weaving machine, in which each of the mechanisms is provided with an individual drive, whereby each of the drives comprises a servomotor with a controllably variable angular speed during one revolution of the servomotor. The angular speed of the servomotor (4) of the beating-up mechanism (1) and the angular speed of the servomotor (5) of the shedding mechanism (2) varies during one revolution of the servomotor (4, 5) according to the selected unevenness of operation (A%) depending on the operating frequency (n) of the weaving machine to maximize the insertion angle and the time for the imple-

mentation of weft insertion, whereby the value of a dynamic parameter selected from the group of dynamic parameters consisting of the quadratic mean of the course of the driving torque, the quadratic mean of the performance, the maximum value of the performance, the mean value of the driving torque, the mean value of the performance, the loading of the members of the transformation mechanisms or the service life of the bearings loaded by reaction forces, and calculated for the interval of one revolution of the main virtual shaft is maintained for all operating frequencies of the machine at the same selected level.

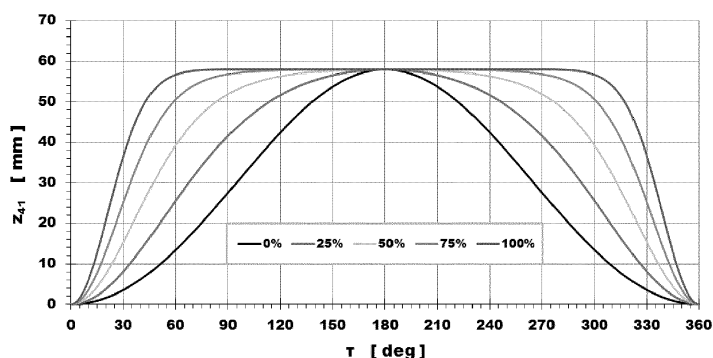


Fig. 7

Description**Technical field**

[0001] The invention relates to a method of controlling the course of the lifting functions of the main mechanisms of a weaving machine, in which each of the mechanisms is provided with an individual drive, whereby each of the drives comprises a servomotor with a controllably variable angular speed during one revolution of the servomotor.

Background art

[0002] The lifting functions of the main mechanisms of a weaving machine, namely of a beating-up mechanism and a shedding mechanism, are set in a fixed manner, as can be seen in Fig. 4, which shows the course of a stroke, for example the stroke of a batten of the beating-up mechanism, depending on the angle of rotation of the main shaft. To insert a weft into a shed, it is necessary to have a free insertion channel in a reed (position above the dashed line) for the entire duration of insertion. Fig. 4 shows an angle of the main (mechanical) shaft for weft insertion ranging from 75° to 285°. This angle is the result of the specific geometry of a joint mechanism (dimensions of the individual members) or of the shape of a cam path of a cam mechanism and cannot be continuously changed. The time t [s] available for weft insertion through the open shed is determined by the main shaft speed (by the machine frequency) and the insertion angle ($285^\circ - 75^\circ = 210^\circ$) and, for example for 600 min^{-1} , it is calculated: $(60 \times 210) / (600 \times 360) = 0.05833 \text{ s}$. In cases where wefts of greater weight or wefts with less affinity for pneumatic insertion need to be inserted into the shed, the speed of the weaving machine must be reduced to create the required insertion time t , and so the machine operates at lower speeds than for which it is designed and, as a result, the use of its proposed technical parameters, as well as productivity, are reduced.

[0003] CZ302120 discloses a weaving machine in which a multi-member mechanism for providing reciprocating motion of a weaving reed with reduced moment of inertia is coupled to a motor with a controllably variable angular speed during one revolution of the motor. A part of a shedding mechanism is also coupled to this motor with a controllably variable angular speed during one revolution during one revolution of the motor. However, the relationship between the motion of the weaving reed and the respective part of the shedding mechanism, usually a heald rod, is unchanged, and so everything mentioned above and shown in Fig. 4 also applies to this relationship.

[0004] In order to reduce the energy intensity of the drive of the weaving machine or in order to increase the performance while maintaining the energy intensity of the weaving machine, separation of the drives of the beating-up mechanism and the shedding mechanism is proposed, whereby each of the mechanisms is provided with an individual drive controlled in the electronic cam mode, each of these mechanisms being coupled to an energy recuperation system.

Principle of the invention

[0005] The object of the present invention is achieved by a method of controlling the course of lifting functions of the main mechanisms of a weaving machine according to the present invention, whose principle consists in that the angular speed of the servomotor of the beating-up mechanism and the angular speed of the servomotor of the shedding mechanism change during their rotation according to the selected unevenness of operation according to adaptive algorithm, whereby in an exemplary embodiment, the value of the quadratic mean of the driving torque determined within an interval of one revolution of the main virtual shaft is maintained at the same selected level for all operating frequencies of the machine. The quadratic mean of the course of the driving torque can be replaced with another dynamic parameter of the weaving machine, such as the quadratic mean of the performance, maximum value of the driving torque, maximum value of the performance, mean value of the driving torque, mean value of the performance, the loading of the members of the transformation mechanisms or the service life of the bearings loaded by reaction forces.

[0006] This solution allows to change the stroke dependence by an adaptive system and maximize the insertion angle, thus enabling operation of the machine at higher speeds, optimizing machine operation with respect to the insertion requirements of a specific weft material and effectively utilizing the dynamic properties of the weaving machine in a wide range of operating speeds.

[0007] In addition, it is not necessary for the unevenness of rotation of the drive of the beating-up mechanism to be equal to the unevenness of rotation of the drive of the shedding mechanism.

Description of drawings

[0008] Fig. 1 shows a basic scheme of a drive of a batten of a beating-up mechanism and of a drive of a heald rod of a shedding mechanism of a weaving machine for the production of leno fabrics, Fig. 2 shows the drive of the batten of the beating-up mechanism and Fig. 3 shows the drive of the heald rod of the shedding mechanism, Fig. 4 shows the

dependence of the stroke of the batten, or of the heald rod z_{41} on the angle τ of rotation of the main mechanical shaft during one revolution of this shaft according to the background art, Fig. 5 shows the course of the angle of rotation φ_{21} of servomotor rotor on the angle τ of rotation of the main virtual shaft during one revolution for the parameters of the unevenness of operation A% adjustable within a range from 0 % to 100 %, Fig. 6 shows the course of the dependence of the revolutions n_{21} of the servomotor rotor on angle τ of rotation of the main virtual shaft during one revolution for the operating frequency of the weaving machine 600 min^{-1} and the parameters of the unevenness of operation A% adjustable within a range from 0% to 100% and finally, Fig. 7 shows the course of the stroke z_{41} of a working member (the weaving reed in the case of a beating-up mechanism and the heald rod in the case of the shedding mechanism) depending on the angle τ of rotation of the main virtual shaft during one revolution for the parameters of the unevenness of operation A% which are adjustable within a range from 0 % to 100 % and after the transformation by a crank mechanism.

Examples of embodiment

[0009] The invention will be described with reference to an example of an air-jet weaving machine for producing leno fabrics. However, it is not limited to this type of weaving machine, but can be used in all weaving machines to control the lifting functions of the main mechanisms, each of these main mechanisms having an individual drive with a controllably variable angular speed during one revolution of the drive.

[0010] The air-jet weaving machine for producing leno fabrics comprises a beating-up mechanism 1 and a shedding mechanism 2.

[0011] The beating-up mechanism 1 comprises a weaving reed 11 which is mounted on a stringer 121 of a batten 12. The batten 12 is mounted in a known manner on the machine frame 3 by means of at least two flexible members 122 of the energy recuperation system of the beating-up mechanism 1, as is schematically shown in Fig. 1. In the exemplary embodiment of Fig. 2, the flexible members 122 are arranged in two planar surfaces between which there is a spacing in the direction of the motion of the stringer 121 of the batten 12 between the insertion position and the beating-up position and the batten 12 is made according to patent CZ 302391 of a carbon-epoxy (CE) composite material or another suitable material. In the embodiment shown, the flexible members 122 consist of leaf springs 1221 which constitute in their upper part an integral part of the stringer 121, whereby both the leaf springs 1221 and the stringer 121 are made of the same CE composite material and form an open profile in the shape of a parallelogram or a general quadrilateral. The beating-up mechanism 1 is provided with an individual drive which is in the illustrated embodiment formed by two servomotors 4 according to UV 29115 with crank rotors 41 which are at one end provided with eccentric pins 411 on which are mounted connecting rods 42 of the beating-up mechanism which are in the exemplary embodiment shown coupled to the batten 12 by means of connecting rod pins 123, formed on the batten 12. The two servomotors 4 with crank rotors 41 are controlled synchronously and have a controllably variable angular speed during one revolution. The servomotors 4 with crank rotors 41 are mounted on the frame 3 of the weaving machine and, in the embodiment shown, are spaced from each other by means of eccentric pins 411 with connecting rods 42. The pins 123 of the connecting rod 42 are formed on the batten 12 below its stringer 121. A weaving reed 11 and related accessories, for example main nozzles 124, blowing nozzles 125, etc., are mounted on the stringer 121 of the batten 12. The servomotors 4 with crank rotors 41 are coupled in a known unillustrated method to an unillustrated control system of the weaving machine.

[0012] The shedding mechanism 2 of the weaving machine comprises a vertically reversibly displaceable heald rod 21 on which is mounted a guide rail 211 of stationary warp threads with holes to receive stationary warp threads which further pass through the lamellae of the weaving reed 11 to a binding point, where they become part of the fabric. The heald rod 21 is coupled to the shedding mechanism with an individual drive with the aid of means which are situated below the weaving plane which is formed by a horizontal plane interspersed with the binding point.

[0013] The heald rod 21 of the shedding mechanism of the weaving machine is slidably mounted on the machine frame in guides (not shown) by means of gliders 23 which are fixedly connected to the heald rod 21. The individual drive of the heald rod 21 is formed by a servomotor 5 with a controllably variable angular speed during one revolution of the servomotor 5. The servomotor 5 of the shedding mechanism is mounted on the frame 3 of the weaving machine and located below the middle part of the heald rod 21. In the embodiment shown, the servomotor 5 of the shedding mechanism 2 is provided with a continuous shaft 51, at the ends of which are arranged crankshafts 511, which are coupled to the heald rod 21 in a known method by means of the connecting rods 52 of the shedding mechanism. In the embodiment shown, the heald rod 21 is made of CE composite material. The heald rod 21 of the shedding mechanism is associated with recuperative members 6 of the energy recuperation system of the shedding mechanism 2.

[0014] In the exemplary embodiment shown in Fig. 3, four recuperative members 6 are arranged below the heald rod 21. Below the middle part of the heald rod 21, a central holder 60 of the inner recuperative members 601 is fixedly mounted on the frame 3 of the weaving machine, to which static stirrups 661 of the inner recuperative members 601 are connected. The movable stirrups 662 of the inner recuperative members 601 are coupled to the connecting rods 52 of the shedding mechanism 2 by means of flexible tow bars 67. Outwards, flexible tow bars 67 of outer recuperation members 602 are mounted on the respective connecting rods 52 of the shedding mechanism 2, whereby the static

stirrups **661** of the outer recuperation members **602** are fixedly mounted on the frame **3** of the weaving machine in the extreme holders **61**, **62** of the outer recuperative members **6**. The inner recuperative member **601** and the outer recuperative member **602** constitute on both sides of the machine a pair of recuperative members **6** which serves for energy recuperation of the shedding mechanism **2**.

[0015] As the heald rod **21** moves, the flexible tow bars **67** also move and carry the movable stirrups **662** of the respective pairs of recuperative members **6**, while the static stirrups **661** do not move, which leads to the deformation of the leaf springs **66** of the respective recuperative members. As the heald rod **21** moves backwards, the leaf springs **66** straighten and recover energy.

[0016] In order to take advantage of all the possibilities provided by the separation of the drives of the beating-up mechanism and the shedding mechanism, whereby the drives are formed by servomotors with a controllably variable angular speed during one revolution of the servomotor, as described above, an adaptive system of controlling the lifting functions of these mechanisms is proposed. The adaptive system consists in the fact that due to the change of unevenness of rotation of the rotors of the respective servomotors depending on the operating frequency of the weaving machine, the maximum insertion angle is achieved, that is, the maximum space or time for the implementation of pneumatic weft insertion while making optimal use of the dynamic characteristics of the mechanisms of the weaving machine and their individual drives by the respective servomotors.

[0017] In the exemplary embodiment, the adaptive system is based on the below dependence for the angle of rotation of the rotor of the servomotor $\varphi_{A(\tau)}$:

$$\varphi_{A(\tau)} = \tau + A * \sin(\tau) + A * \sin[\tau + A * \sin(\tau)]$$

where τ is the angle of rotation of the main "virtual" shaft [rad]
(calculated by the control system) and defined by the relation:

$$\tau = \Omega * t$$

where Ω is circular frequency [rad/s], determined by the relation:

$$\Omega = \frac{2 * \pi * n}{60} = 2 * \pi * f$$

t - time [s] n - machine revolutions [1/min]

where $A = \frac{A\%}{100}$ is a parameter expressing the degree of uneven operation of the beating-up shedding mechanism in [%], and is continuously variable within a range from 0 % to 100 %.

[0018] The course of the dependence of the angle φ_{21} of rotation of the rotor of the servomotor on the angle τ of rotation of the main (virtual) shaft for the parameters of the unevenness of operation $A\%$ from 0 % to 100 % are graphically represented in Fig. 5, from which it is evident that for $A\% = 0\%$ the dependence is linear (evenly linearly increasing) and with increasing unevenness $A\%$, also the unevenness of the course of the angle φ_{21} of the servomotor rotation on the angle τ of rotation of the main virtual shaft increases, which, for example, for the beating-up mechanism and theoretical unevenness $A\% = 100\%$ means that the weaving reed practically moves from the beating-up position to the rear dead center after reaching the angle $\tau = 90^\circ$, remains there until $\tau = 270^\circ$ and after reaching $\tau = 360^\circ$ moves back to the beating-up position. For the shedding mechanism and theoretical unevenness $A\% = 100\%$, this means that the heald rod practically moves from the initial lower position after reaching the angle $\tau = 90^\circ$ to the top dead center, in which it remains until $\tau = 270^\circ$ and then it moves back to the initial lower position when the angle $\tau = 360^\circ$ is reached.

[0019] The above corresponds to the course of the dependence of the speed n_{21} of the rotor of the servomotor on the angle τ of rotation of the main virtual shaft, during one revolution for the operating frequency of the weaving machine 600 min^{-1} and the parameters of the unevenness of operation $A\%$ adjustable in the range from 0 % to 100 %, as graphically represented in Fig. 6. With unevenness $A\% = 0$, the speed is constant and is equal to the operating frequency n of the weaving machine, i.e. the nominal speed of the main virtual shaft, and their course is therefore constant (horizontal line), while at unevenness $A\% = 100\%$, the rotor of the servomotor has high speeds in the first part of its movement (from $\tau = 0^\circ$ until reaching the angle $\tau = 90^\circ$). The high speeds quickly decrease towards zero and again begin to increase sharply from $\tau = 270^\circ$ until the maximum is reached at the angle $\tau = 360^\circ$.

[0020] Similarly, Fig. 7 graphically represents the course of the stroke z_{41} of the working member (the weaving reed in the case of the beating-up mechanism and the heald rod in the case of the shedding mechanism) depending on the angle τ of rotation of the main virtual shaft, during one revolution of the main virtual shaft for the parameters of unevenness of operation A% adjustable in the range from 0% to 100% and after the transformation by the crank mechanism.

[0021] The adaptive system of controlling the lifting functions of the beating-up mechanism and the shedding mechanism is designed for the parameters of unevenness of operation A% such that for the set operating frequencies n of the weaving machine, i.e. for the selected nominal speed of the main virtual shaft of the weaving machine, the value of the quadratic mean of the course of the driving torque of the servomotor calculated for the interval of one revolution of the main virtual shaft is equal to the same selected value,

$${}^{\text{RMS}}M_{h21} = 17 \text{ Nm}$$

and was at the same selected level for all the set operating frequencies of the machine as shown in the following table, indicating:

n	operating frequency of the weaving machine, i.e. speed of the main virtual shaft
A%	parameter of unevenness of operation of the servomotor, that is, of the crankshaft
min n_{21}	actual minimum speed of the servomotor, that is, of the crankshaft
max n_{21}	actual maximum speed of the servomotor, that is, of the crankshaft
$\tau_{\text{insertion}}$	insertion angle of rotation of the main "virtual" shaft
$\tau_{\text{insertion}}$	time for insertion
RMS P	quadratic mean of the performance of the servomotor for the interval of one period
max P	maximum value of the performance of the servomotor
RMS M_h	quadratic mean of the driving torque of the servomotor for the interval of one revolution of the main virtual shaft
max M_h	maximum value of the driving torque of the servomotor

PARAMETERS OF AN EXEMPLARY EMBODIMENT OF A SHEDDING MECHANISM

[0022]

n	A%	min n_{21}	max n_{21}	τ of insertion	$\tau_{\text{insertion}}$	RMS P	max P	RMS M_h	max M_h
[rpm]	[%]	[RPM]	[RPM]	[deg]	[ms]	[W]	[W]	[Nm]	[Nm]
750	32.475	342	1316	202.0	44.889	1603	3621	17.00	37.10
725	34.465	311	1311	206.0	47.356	1585	3633	17.00	37.9
700	36.618	281	1307	212.0	50.476	1568	3650	17.00	37.90
675	38.952	252	1303	216.0	53.333	1554	3672	17.00	38.36
650	41.489	223	1301	222.0	56.923	1542	3703	17.00	38.88
625	44.251	194	1301	226.0	60.267	1532	3744	17.00	39.45
600	47.263	167	1301	232.0	64.444	1526	3794	17.00	40.08
575	50.552	141	1303	238.0	68.986	1523	3853	17.00	40.77
550	54.143	116	1307	244.0	73.939	1523	3924	17.00	41.51
525	58.062	92	1312	250.0	79.365	1526	4005	17.00	42.31
500	62.330	71	1318	256.0	85.333	1530	4091	17.00	43.14
475	66.965	52	1324	262.0	91.930	1534	4176	17.00	43.93
450	71.982	35	1331	268.0	99.259	1536	4257	17.00	44.61
425	77.387	22	1337	274.0	107.451	1532	4320	17.00	45.08
400	83.182	11	1342	280.0	116.667	1520	4349	17.00	45.22

[0023] The optimization solution of the problem was performed numerically, at discrete points for the varying parameters

of unevenness A% and the practical range of nominal speeds of the main virtual shaft of the weaving machine, and subsequently approximated by continuous analytic function. The other values shown in the Table are key physical quantities of the solved system and they also need to be critically assessed.

[0024] The optimization of parameters of unevenness of operation A% can also be performed for other dynamic parameters of the weaving machine, where the value of the dynamic parameter selected from the group of dynamic parameters: (the quadratic mean of the course of the driving torque, the quadratic mean of the performance, the maximum value of the driving torque, the maximum value of the performance, the mean value of the driving torque, the mean value of the performance, the loading of the members of the transformation mechanisms or the service life of the bearings loaded by reaction forces) and (the value) calculated for the interval of one period is maintained at the same selected level for all operating frequencies of the machine.

Industrial applicability

[0025] The method according to the invention can be used in weaving machines which have individual drives of the beating-up mechanism and the shedding mechanism, and both these drives are controlled in the electronic cam mode. The method can also be used in weaving machines in which the drive of the beating-up mechanism and the shedding mechanism is common but consists of a servomotor controlled in the electronic cam mode.

List of references

[0026]

1	beating-up mechanism
11	weaving reed
12	batten
121	stringer of the batten
122	flexible members of the energy recuperation system of the beating-up mechanism
1221	leaf springs of the batten
123	eyes of the batten
2	shedding mechanism
21	heald rod
211	guide rail of stationary warp threads
23	sliders of the heald rod
3	frame for the weaving machine
4	servomotors with crank rotors
41	crank rotors
411	eccentric pins
42	connecting rod of the beating-up mechanism
5	servomotor of the shedding mechanism
51	continuous shaft
511	crankshaft
52	connecting rod of the shedding mechanism
6	recuperative member
60	central holder of the inner recuperative members
601	inner recuperative member
602	outer recuperative member
61, 62	extreme holders of the outer recuperative members
67	flexible tow bar of the recuperative member
$\varphi_{A(\tau)}$	angle of rotation of the servomotor
τ	angle of rotation of the main virtual shaft [rad]
Ω	circular frequency [rad/s]
T	time [s]
n	operating frequency of the weaving machine, i.e., speed of the main virtual shaft
A%	parameter of the unevenness of operation of the servomotor, i.e., of the crankshaft
$\min n_{21}$	actual minimum speed of the servomotor, i.e., of the crankshaft
$\max n_{21}$	actual maximum speed of the servomotor, i.e., of the crankshaft
$\tau_{\text{of insertion}}$	insertion angle of rotation of the main "virtual" shaft
$\tau_{\text{insertion}}$	time for insertion

RMSp	quadratic mean of the performance of the servomotor for the interval of one period
max p	maximum value of the performance of the servomotor
RMS M_h	quadratic mean of the driving torque of the servomotor for the interval of one period of the main virtual shaft
max M_h	maximum value of the driving torque of the servomotor

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Claims

1. A method of controlling the course of lifting functions of a beating-up mechanism (1) and a shedding mechanism (2) of a weaving machine, in which each of the mechanisms is provided with an individual drive, whereby each of the drives comprises a servomotor (4, 5) with a controllably variable angular speed during one revolution of the servomotor (4,5), **characterized in that** the angular speed of the servomotor (4) of the beating-up mechanism (1) and the angular speed of the servomotor (5) of the shedding mechanism (2) varies during one revolution of the servomotor (4, 5) according to the selected unevenness of operation (A%) depending on the operating frequency (n) of the weaving machine to maximize the insertion angle and the time to implement weft insertion, whereby the value of a dynamic parameter selected from a group of dynamic parameters consisting of the quadratic mean of the course of the driving torque, the quadratic mean of the performance, the maximum value of the performance, the mean value of the driving torque, the mean value of the performance, the loading of the members of the transformation mechanisms, or the service life of the bearings loaded by reaction forces, and calculated for the interval of one revolution of the main virtual shaft is maintained for all the operating frequencies of the machine at the same selected level.
2. The method according to claim 1, **characterized in that** the dynamic parameter is the quadratic mean of the course of the driving torque ($^{RMS}MH_{21}$).
3. The method according to claim 1 or 2, **characterized in that** the unevenness of rotation of the drive of the beating-up mechanism equals the unevenness of rotation of the drive of the shedding mechanism.
4. The method according to claim 1 or 2, **characterized in that** the unevenness of rotation of the drive of the beating-up mechanism is different from the unevenness of rotation of the drive of the shedding mechanism

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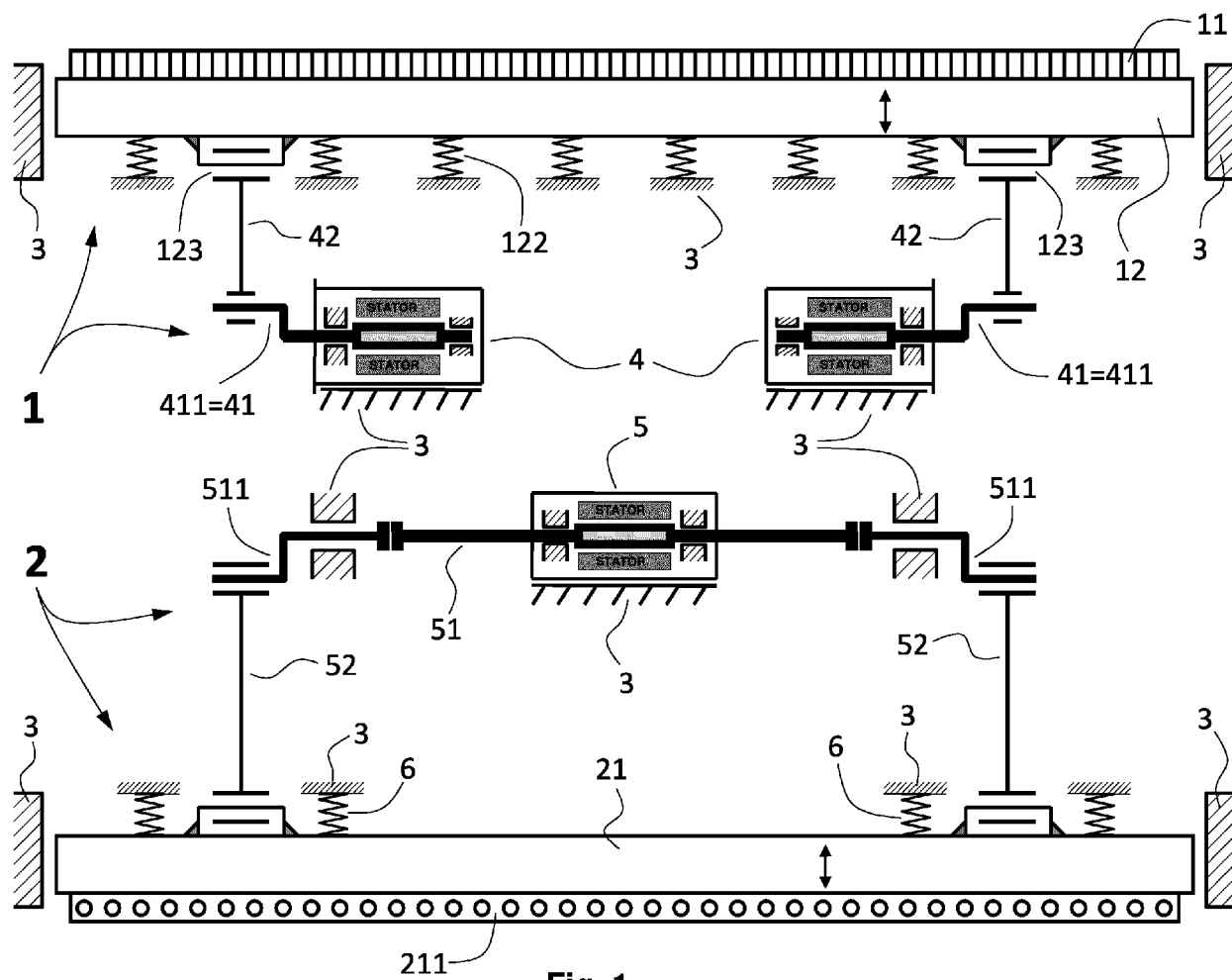


Fig. 1

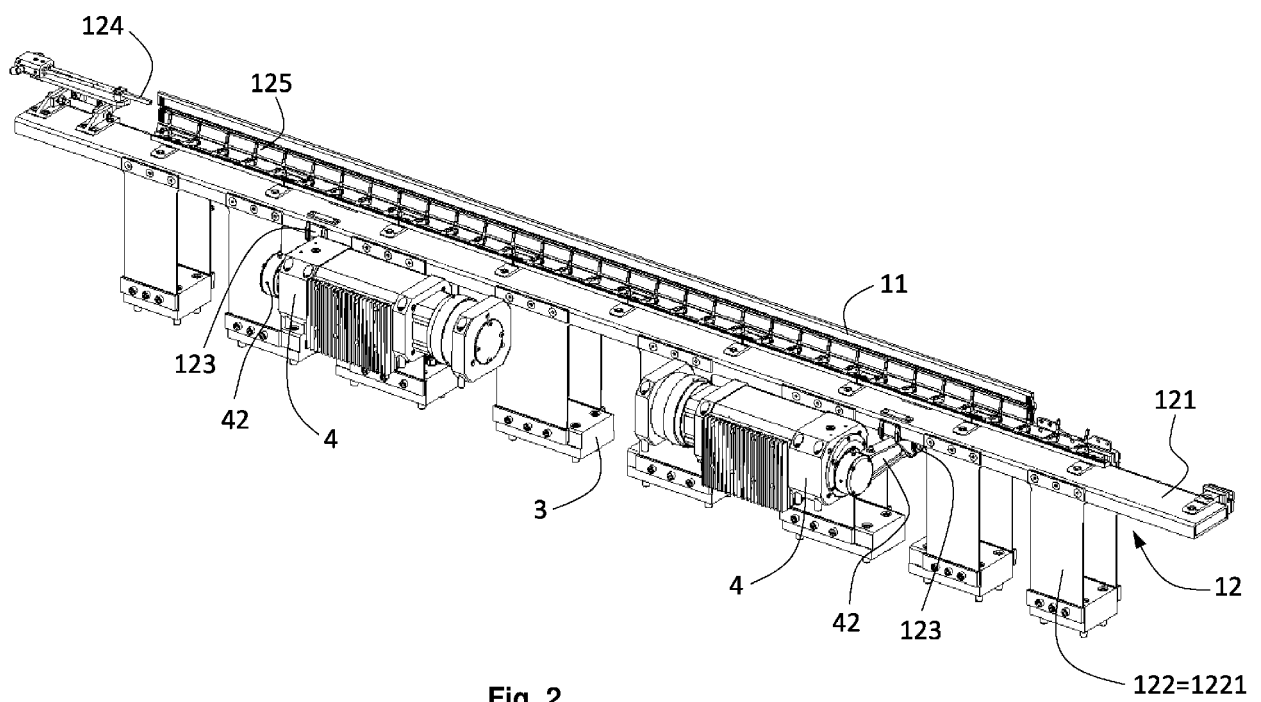


Fig. 2

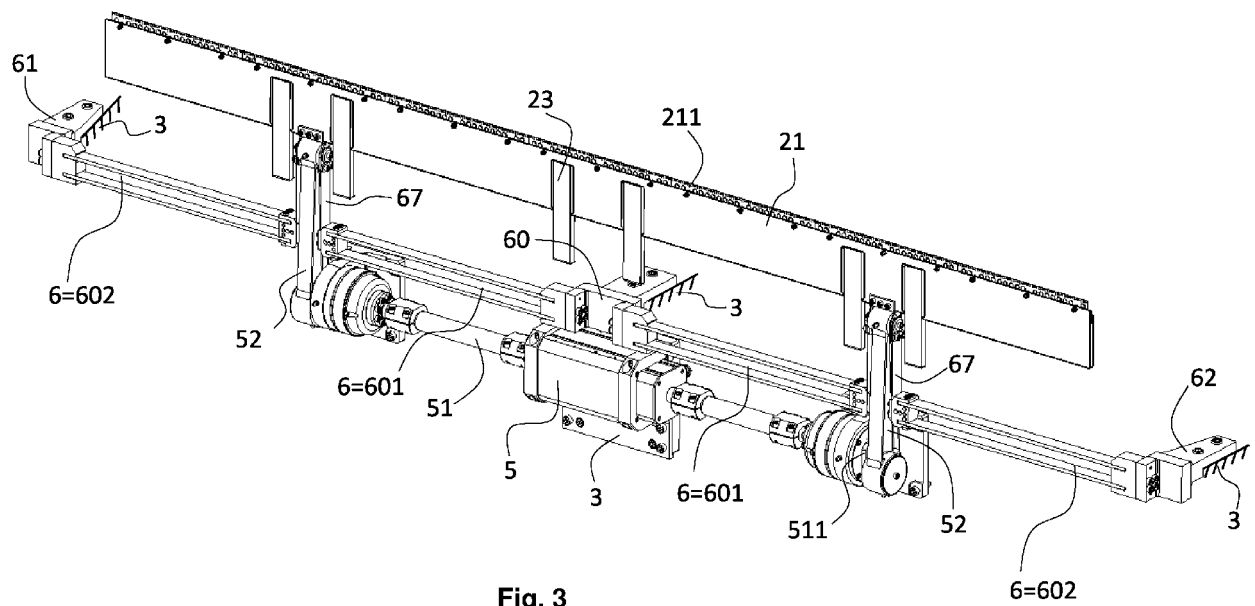


Fig. 3

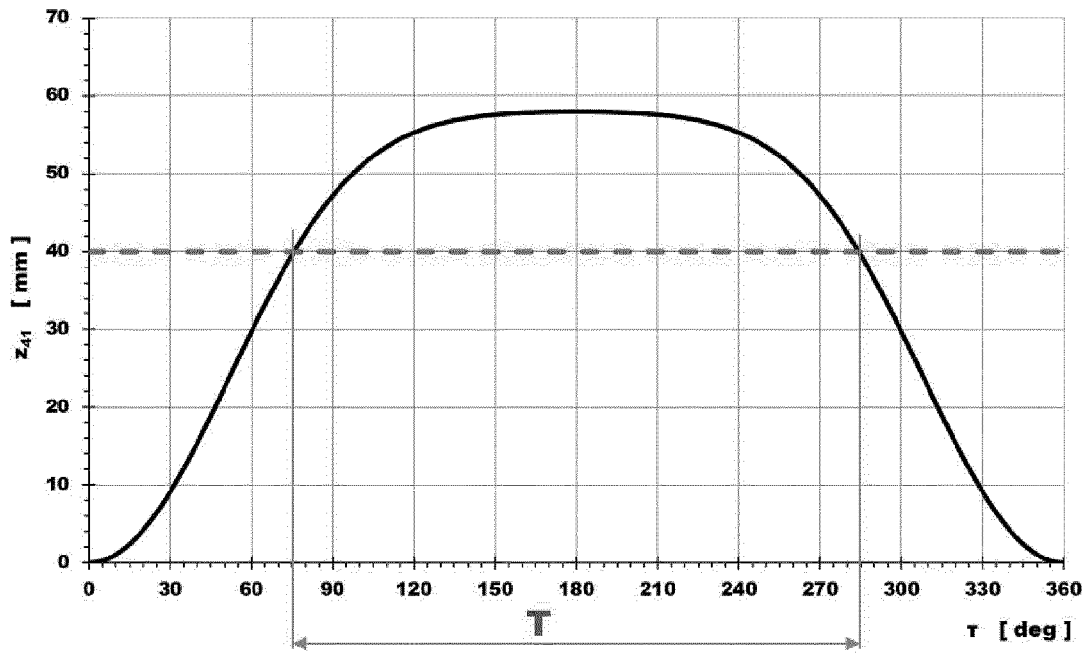


Fig. 4

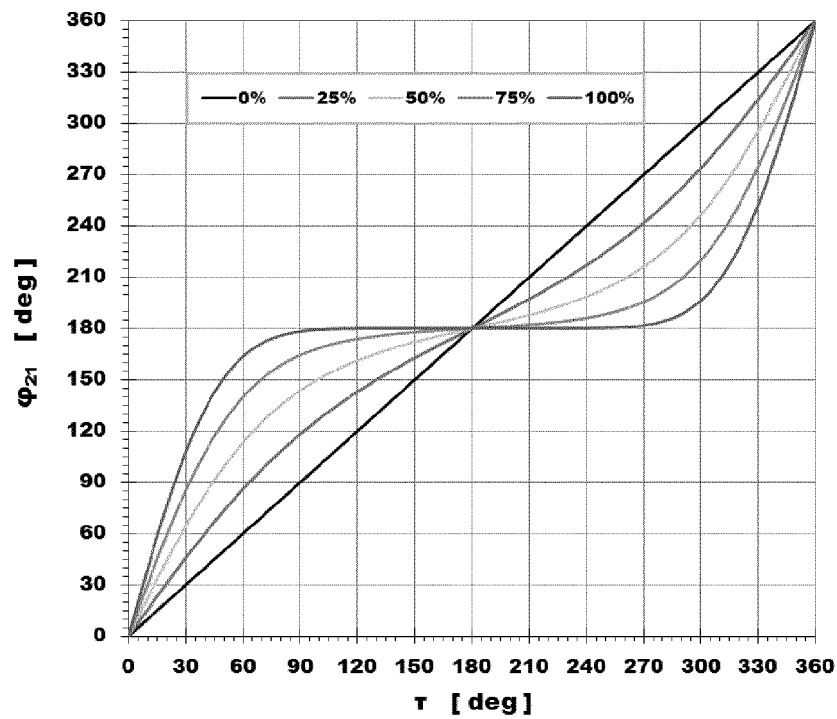


Fig. 5

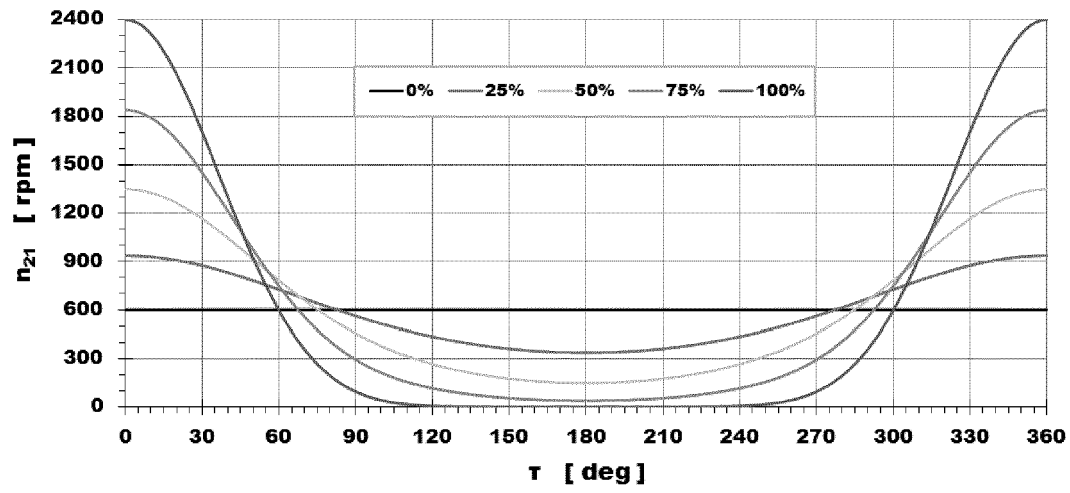


Fig. 6

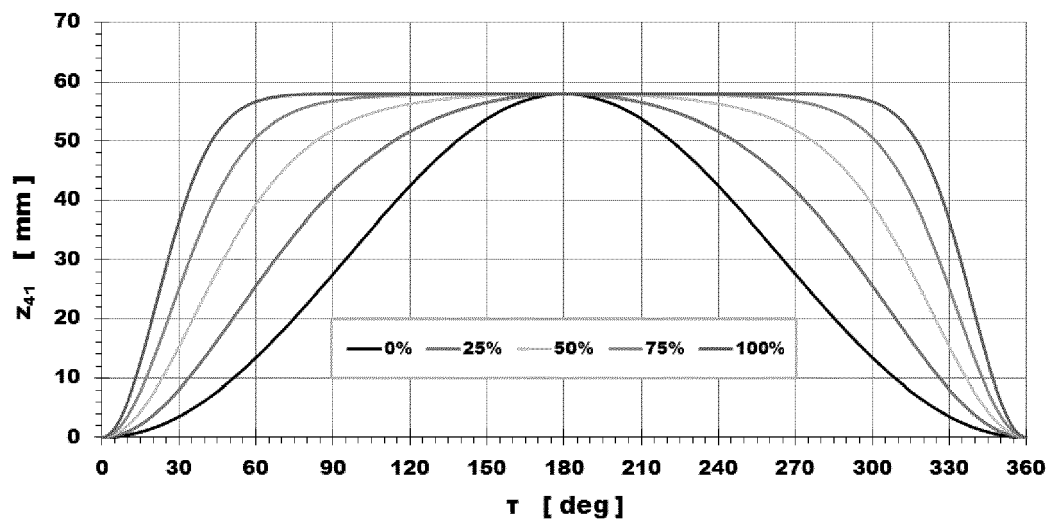


Fig. 7



EUROPEAN SEARCH REPORT

Application Number
EP 20 17 9228

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The present search report has been drawn up for all claims			
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 20 17 9228

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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