

Description

The present invention relates to an erosion machine having a rotary drive mechanism for the sleeve or the work holder.

As is known, such machines permit extremely precise machining of workpieces by electroerosive material removal. In order to achieve precise shaping of a workpiece, the parts and elements of the erosion machine must be manufactured and operate with at least the same level and if possible an even higher level of precision.

In the exemplary case of a cavity sinking EDM machine, an electrode is used to machine the workpiece, which is held in vertically adjustable and rotatable fashion in the sleeve of the machine. To rotate the sleeve and hence the electrode a rotary drive is provided, which is customarily actuated by electric motor. In order to bring the sleeve into a desired angular orientation, the sleeve is rotated by an electric motor via a reduction gear unit.

In known rotary drive mechanisms of this kind, the transmission backlash between motor shaft, gear unit and sleeve is one of the main problems. It was therefore necessary to use extremely precisely manufactured reduction gear units and power transmission elements in order to be able to achieve the required positioning accuracy as regards the angle of rotation of the sleeve. However, drives of this kind are very expensive, require costly servicing and are subject to relatively rapid wear, which impairs the accuracy which can be achieved. The same applies to rotary drives which allow the work holder to be rotated.

It is the object of the invention to create an erosion machine having a rotary drive of the type stated at the outset which no longer has the disadvantages mentioned above, which can therefore be produced at a favourable price, which makes possible a further increase in accuracy of positioning as regards the angle of rotation and which permits rapid rotation of the sleeve

or the work holder into a desired angular position.

According to the invention, the object set is achieved by the fact that the rotary drive mechanism comprises at least two electric motors which can be reversed as regards the direction of rotation and one reduction gear unit allocated to each electric motor, which has an input member coupled to the electric motor and driven by the latter and an output member coupled to the sleeve or the work holder and driving the latter, a shaft encoder coupled to the sleeve or the work holder and a control device, connected to the shaft encoder and the electric motors, which always drives at least two of the electric motors by a different amount and/or in different directions.

The actual power train, namely the reduction gear unit and the associated power transmission elements, are thereby always held under a certain prestress, which renders inoperative any backlash in the gear unit and between the gears and the elasticity which is always present in any mechanical system. The advantage is that the reduction gear unit and the power transmission elements can be of much simpler design and therefore more favourable in price. Even if the transmission backlash increases in the course of time, for example due to wear, this phenomenon does not exert a disadvantageous influence on accuracy of positioning.

In general, two electric motors will be used ; however, depending on the application, it is also possible to provide a larger number thereof.

The feature "by an unequal amount and/or in different directions" is to be understood as follows, depending on the operating state of the mechanism:

1. When the sleeve or the work holder is at a standstill, the two electric motors are driven by the same amount but in opposite directions.
2. When the sleeve or the work holder is driven at a first, relatively high speed of rotation, the two electric motors are

driven by a different amount but in the same direction.

3. When the sleeve or the work holder is driven at a second, relatively low speed of rotation, the two electric motors are driven by a different amount and in opposite directions.

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10 This means therefore that the two electric motors never act identically on the sleeve or the work holder but always produce a certain prestress in the power train.

15 Preferably, one electric motor is driven by the same amount and in the same direction both when the sleeve or the work-holding device is at a standstill and at the second, relatively low speed of rotation of the sleeve or the work-holding device. It can thereby be ensured that it is impossible for an undefined state to arise in the power train at the beginning of the rotary movement of the sleeve or the work-holding device since
20 this one electric motor always exerts a certain torque in a first direction of rotation both at a standstill and during the rotation of the sleeve or the work-holding device while the other electric motor exerts a higher torque than the first-mentioned electric motor at the moment of start-up and thus rotates the sleeve or the
25 workholder.

In a further development of the subject-matter of the invention, it is possible to provide that upon the transition from the standstill of the sleeve or the work
30 holder to the first, relatively high speed of rotation in the same direction of rotation, one electric motor is switched over to higher speed and the other electric motor is switched over to the reverse direction of rotation, the reversing of said other electric motor
35 being carried out with a delay. This measure too, although not absolutely essential due to the mass inertia of the power train, aims to prevent an undefined or unloaded state arising in the drive.

An illustrative embodiment of the erosion machine

according to the invention is explained in greater detail below with reference to the attached drawings. In the drawings:

5 Fig. 1 shows a partially cut-away plan view of a rotary drive mechanism for the sleeve of an erosion machine;

 Fig. 2 shows a partially cut-away side view of the mechanism of Fig. 1;

10 Fig. 3 shows a diagram to illustrate the action of the rotary drive, and

 Figs. 4a and 4b show two details from a diagram corresponding to Fig. 3.

 According to Fig. 1, the rotary drive mechanism comprises a bearing housing 1, in which a sleeve 2 is
15 mounted rotatably by means known per se and not shown in detail. Provided above the sleeve 2 is a coaxially arranged shaft encoder 3, which is coupled in torsionally rigid fashion to the sleeve, serves as an angular position indicator and is connected to a control unit
20 (likewise not shown).

 The sleeve 2 carries a spur gear 4, via which it is driven and which is in engagement with two intermediate gears 5a and 5b. The latter for their part are in engagement with the gears 7a and 7b, which serve as
25 output members of in each case one reduction gear unit 6a and 6b. Two electric motors 8a and 8b, which are arranged next to the two gear units 6a and 6b, each carry on their output shaft 9a and 9b a pulley 10a and 10b, which are connected via in each case one toothed belt 11a and 11b
30 to the associated pulley 12a and 12b serving as input member.

 It will be obvious to a person skilled in the art that a power train of this or a similar type has a not inconsiderable elasticity and that there is a certain
35 backlash in the gear units 6a and 6b and between the intermeshing gears 4, 5a, 7a and 4, 5b and 7b respectively, which it is possible to minimise constructionally only with difficulty and by costly measures.

 According to the invention, these disadvantages

are now avoided by the fact that the two electric motors 8a and 8b are never driven identically by the control unit. In other words, at standstill one electric motor 8a is driven, for example, in the clockwise direction and the other electric motor 8b in the anticlockwise direction, but both are driven in such a way that they exert a torque of equal magnitude on the power train and hence on the gear 4 of the sleeve 2. The power train is thereby under a certain prestress, with the result that all backlash is eliminated and the elasticity is compensated. If the sleeve 2 is to be rotated slowly, for example into a proximate angular position, the torque at one of the electric motors is increased, for example at motor 8a, according to the desired direction of rotation, while the operating state of the other electric motor 8b does not change at all. If, however, the sleeve 2 is to be rotated rapidly into a more distant angular position, the torque at one of the electric motors is increased, for example at motor 8a, again according to the desired direction of rotation, and the other electric motor 8b is reversed but driven in such a way that it delivers a low torque.

In the schematic representation of Fig. 3, these relationships are represented in simplified fashion. The solid line here relates to electric motor 8a while the dashed line relates to electric motor 8b.

In the period t_0 to t_1 , the sleeve is at a standstill, motor 8a delivering a positive torque $+M_1$ and motor 8b delivering a negative torque $-M_1$; the two torques are equal in magnitude but opposite in direction. At time t_1 , the sleeve is to be rotated into a comparatively distant angular position. For this purpose, the torque produced by motor 8a is increased from the value $+M_1$ to the value $+M_3$; motor 8b is switched over as regards its direction of rotation, with the result that it delivers a torque with the value $+M_2$. The value $+M_2$ is smaller than the value $+M_3$, with the result that the prestress in the power train is maintained. Let it be assumed that at time t_2 an angular position has been reached which is already quite close to the desired position. At this time motor 8b is

therefore switched over as regards its direction of rotation and, as during standstill, again delivers a torque $-M_1$. It now acts as an intensified brake on motor 8a and increases the prestress in the power train. As soon as the desired position has been reached, at time t_3 , the torque of motor 8a is reduced to the value $+M_1$, with the result that the sleeve stands still in the period from t_3 to t_4 . Motor 8b, on the other hand, remains unchanged and continues to supply the negative torque with the value $-M_1$.

Let it be assumed that at time t_4 the sleeve is to be rotated into a neighbouring angular position in the same direction of rotation. For this purpose, the torque of motor 8a is increased to the value $+M_2$ while motor 8b is left in its previous operating state. At time t_5 , when the desired new position has been reached, the torque of motor 8a is reduced to the value $+M_1$, the torques of the two motors 8a and 8b thus balancing each other out again and the sleeve standing still. At time t_6 , the sleeve is to be rotated back into its previous, neighbouring position. For this purpose, the torque of motor 8b is increased from the value $-M_1$ to the value $-M_2$ while motor 8a is left unchanged at the value $+M_1$: the sleeve rotates in the opposite direction under the influence of motor 8b.

At time t_7 , the new position has been reached and the torque of motor 8b is reduced to the value $-M_1$ again so that the sleeve stands still until time t_8 . A greater rotation of the sleeve in the negative direction is then to be effected. For this purpose, the torque of motor 8b is increased to the value $-M_2$ and motor 8a simultaneously reversed until it reaches a torque $-M_2$, which is lower than the torque $-M_3$. It thus acts here as a moderate brake and in this way maintains the prestress in the power train. When the new desired position has almost been reached, i.e. at time t_9 , motor 8a is reversed again, now delivering the torque $+M_1$ again and thus braking motor 8b more strongly. At time t_{10} , the new desired position has been reached and the torque of motor 8b is reduced to the

value $-M_1$, while motor 8a continues to deliver a positive torque $+M_1$; the sleeve stands still until time t_{11} .

From the above explanations it is evident that the two motors 8a and 8b always act differently on the power train formed by the toothed belts 11a and 11b, gear units 6a and 6b, gears 5a and 5b and 7a and 7b respectively and gear 4 and as a result always produce a prestress. Although, during the rapid rotation of the sleeve, this prestress is lower, it meets the accuracy requirements, which are not as high in this case.

Under certain circumstances, a critical torque could occur at times t_1 and t_8 , namely when one motor is reversed and the torque of the other simultaneously increased. If the mass inertia of the power train is not sufficient to damp this torque, provision could be made, according to a further development, for the reversal of the one motor and the torque increase of the other not to take place exactly simultaneously.

From Fig. 4a it can be discerned that the torque of motor 8a is increased precisely at time t_1 and that the reversal of motor 8b and the raising of the torque to the value $+M_2$ is effected with a slight time delay Δt . It is thereby guaranteed that motor 8b is only reversed when motor 8a has reached its predetermined torque and thus maintains the prestress in the power train during the acceleration of motor 8a. The situation according to Fig. 4b at time t_8 is a corresponding one: motor 8a is reversed only after a delay time t , when motor 8b has reached its required torque $-M_3$.

The ratios of the magnitudes of the torques M_1 , M_2 and M_3 depend on the respective application. As a reference point, it can be assumed that the value of M_1 is about 15 - 40 %, preferably about 20 %, and the value of M_2 about 60 - 85 %, preferably about 80 %, of the value of M_3 .

With the rotary drive mechanism according to the invention, all backlash in the gear unit and between the gears is eliminated or rendered inoperative and the elasticity in the entire power train is compensated. An

exceptionally high degree of positioning accuracy as regards the angle of rotation is therefore possible, being of the order of $1/1000$ angular degrees, without the necessity to employ costly, precise and wear-prone drive elements. The sleeve or the work holder can be rotated very rapidly into a particular position and the rotary motion can be stopped immediately without overshoot. The latter is particularly important in spark erosion since as the electrode is moved up to the workpiece a spark occurs suddenly; at this moment, the movement must be stopped immediately. It is impossible to state with certainty at what point this occurs.

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Patent claims

1. Erosion machine having a rotary drive mechanism for the sleeve or the work holder, characterised in that the rotary drive mechanism has at least two electric motors (8a, 8b) which can be reversed as regards the direction of rotation and one reduction gear unit (6a, 6b) allocated to each electric motor, which has an input member (12a, 12b) coupled to the electric motor and driven by the latter, and an output member (7a, 7b) coupled to the sleeve (2) or the work holder and driving the latter, and in that it has a shaft encoder (3) coupled to the sleeve or the work holder and a control device, connected to the shaft encoder and the electric motors, which always drives at least two of the electric motors (8a, 8b) by a different amount and/or in different directions.

2. Erosion machine according to Claim 1, characterised in that two electric motors (8a, 8b) are provided.

3. Erosion machine according to Claims 1 and 2, characterised in that, when the sleeve (2) or the work holder is at a standstill, the two electric motors (8a, 8b) are driven by the same amount but in opposite directions.

4. Erosion machine according to Claims 1 and 2, characterised in that, when the sleeve or the work holder is driven at a first, relatively high speed of rotation, the two electric motors (8a, 8b) are driven by a different amount but in the same direction.

5. Erosion machine according to Claims 1 and 2, characterised in that, when the sleeve or the work holder is driven at a second, relatively low speed of rotation, the two electric motors (8a, 8b) are driven by a different amount and in opposite directions.

6. Erosion machine according to Claims 3 and 5, characterised in that one electric motor (8a or 8b) is driven by the same amount and in the same direction both



when the sleeve or the work-holding device is at a standstill and at the second, relatively low speed of rotation of the sleeve or the work-holding device.

5 7. Erosion machine according to one or more of
Claims 3 to 6, characterised in that, upon the transition
from the standstill of the sleeve or the work holder to
the first, relatively high speed of rotation in the same
direction of rotation, one electric motor (8a or 8b) is
switched over to higher speed and the other electric
10 motor (8b or 8a) is switched over to the reverse
direction of rotation, the reversing of said other
electric motor (8b or 8a) being carried out with a delay.



As printed

Claims

1. Erosion machine having a rotary drive mechanism for the sleeve or the work holder, characterised in that the rotary drive mechanism has at least two electric motors (8a, 8b) which can be reversed as regards the direction of rotation and one reduction gear unit (6a, 6b) allocated to each electric motor, which has an input member (12a, 12b) coupled to the electric motor and driven by the latter, and an output member (7a, 7b) coupled to the sleeve (2) or the work holder and driving the latter, and in that it has a shaft encoder (3) coupled to the sleeve or the work holder and a control device, connected to the shaft encoder and the electric motors, which always drives at least two of the electric motors (8a, 8b) by a different amount and/or in different directions.

2. Erosion machine according to Claim 1, characterised in that two electric motors (8a, 8b) are provided.

3. Erosion machine according to Claims 1 and 2, characterised in that, when the sleeve (2) or the work holder is at a standstill, the two electric motors (8a, 8b) are driven by the same amount but in opposite directions.

4. Erosion machine according to Claims 1 and 2, characterised in that, when the sleeve or the work holder is driven at a first, relatively high speed of rotation, the two electric motors (8a, 8b) are driven by a different amount but in the same direction.

5. Erosion machine according to Claims 1 and 2,

characterised in that, when the sleeve or the work holder is driven at a second, relatively low speed of rotation, the two electric motors (8a, 8b) are driven by a different amount and in opposite directions.

6. Erosion machine according to Claims 3 and 5, characterised in that one electric motor (8a or 8b) is driven by the same amount and in the same direction both when the sleeve or the work-holding device is at a standstill and at the second, relatively low speed of rotation of the sleeve or the work-holding device.

7. Erosion machine according to one or more of Claims 3 to 6, characterised in that, upon the transition from the standstill of the sleeve or the work holder to the first, relatively high speed of rotation in the same direction of rotation, one electric motor (8a or 8b) is switched over to higher speed and the other electric motor (8b or 8a) is switched over to the reverse direction of rotation, the reversing of said other electric motor (8b or 8a) being carried out with a delay.

Revendications

1. Machine à érosion, équipée d'un dispositif d'entraînement rotatif pour la broche ou le support de la pièce à usiner, caractérisée en ce que le dispositif d'entraînement rotatif comporte au moins deux moteurs électriques (8a, 8b) à sens de rotation réversible et un mécanisme réducteur (6a, 6b) associé à chaque moteur électrique, qui comporte un élément d'entrée (12a, 12b) couplé au moteur électrique et entraîné par celui-ci, ainsi qu'un élément de sortie (7a, 7b) couplé à la broche (2) ou au support de la pièce à usiner et entraînant celui-ci, et en ce qu'elle comporte un générateur d'impulsions de rotation (3) couplé à la broche ou au support de la pièce à usiner ainsi qu'un appareil de commande relié au générateur d'impulsions de rotation et aux moteurs électriques, qui entraîne au moins deux des moteurs électriques (8a, 8b) en permanence de façon inégale en quantité et/ou sens.

2. Machine à érosion selon la revendication 1, caractérisée en ce que deux moteurs électriques (8a, 8b) sont prévus.

3. Machine à érosion selon les revendications 1 et 2, caractérisée en ce que les deux moteurs électriques (8a, 8b) sont entraînés, lors de l'arrêt de la broche (2) ou du support de la pièce à usiner, de la même quantité mais dans des sens opposés.

4. Machine à érosion selon les revendications 1 et 2, caractérisée en ce que les deux moteurs électriques (8a, 8b) sont entraînés, lors de l'entraînement de la broche ou du support de la pièce à usiner à une première vitesse de rotation supérieure, d'une quantité différente, mais dans le même sens.

5. Machine à érosion selon les revendications 1 et 2, caractérisée en ce que les deux moteurs électri-



ques (8a, 8b) sont entraînés, lors de l'entraînement de la broche ou du support de la pièce à usiner, à une seconde vitesse de rotation, inférieure, d'une quantité différente et selon des sens opposés.

6. Machine à érosion selon les revendications 3 et 5, caractérisée en ce qu'un des moteurs électriques (8a ou 8b) est entraîné, aussi bien lors de l'arrêt que lors de la seconde vitesse de rotation, inférieure, de la broche ou du support de la pièce à usiner, de la même quantité et dans le même sens.

7. Machine à érosion selon l'une quelconque des revendications 3 à 6, caractérisée en ce qu'un des moteurs électriques (8a ou 8b) est commandé, lors du passage de l'arrêt de la broche ou du support de pièce à usiner à la première vitesse de rotation, supérieure, dans le même sens de rotation à une vitesse supérieure, et l'autre moteur électrique (8b ou 8a) est commandé selon un sens de rotation inversé, la commande dudit autre moteur électrique (8b ou 8a) s'effectuant de façon différée.

