very little material removal, such that the process times during double-side polishing are lengthened unnecessarily.

Object

Consequently, embodiments of the present invention seek to improve~~is based on the object of improving~~ the known double-side group processing methods, and in particular the corresponding grinding method, such that the thickness deviations from batch to batch and between the actual and desired values are reduced. In this case, the small thickness deviations from workpiece to workpiece and within a workpiece (plane-parallelism of the two surfaces) and also the good flatness of the workpiece which are obtained in accordance with the prior art must be maintained.

Achieving the object

According to an aspect of the invention, there is provided~~The object is achieved by means of~~ a method for the simultaneous double-side material-removing processing of at least three workpieces between a rotating upper working disk and a rotating lower working disk of a double-side processing apparatus, wherein the workpieces lie in freely movable fashion in a respective opening in a guide cage and are moved by the latter under pressure in a working gap formed between the two working disks, wherein, upon a preselected target thickness of the workpieces being attained, a deceleration process is initiated, during which the angular velocities $\omega_i(t)$ of all the drives i of the upper working disk, of the lower working disk and of the guide cage are reduced to a standstill of the two working disks and of the guide cage, wherein the reducing being carried out such that all ratios $\frac{\omega_{i,ACTUAL}(t)}{\omega_{j,ACTUAL}(t)}, i \neq j$ of the angular velocities $\omega_{i,ACTUAL}(t)$ deviate by no more than 10 % from the initial ratios $\frac{\omega_i(t=0)}{\omega_j(t=0)}, i \neq j$, of the angular velocities $\omega_i(t=0)$ corresponding to when the preselected target thickness was attained ($t=0$).

~~angular velocities $\omega_i(t)$ of all the drives i are reduced in such a way that, during the deceleration phase, the ratios of all the angular velocities $\omega_i(t)$ to one another as a function of the time t deviate by not more than 10% and preferably by not more~~

~~than 5% from the ratios at the instant at which the preselected target thickness is attained.~~

In this case, it is possible to reduce the angular velocities $\omega_i(t)$ of the drives i during the deceleration process in accordance with the formula $\omega_i(t) = \omega_{i,0} - \frac{k_i}{J_i} t$, i.e. linearly with time.

However, it is preferred for the magnitude of the change in the angular velocity $\omega_i(t)$ of each drive i per unit time to increase in the course of the deceleration process. This is preferably achieved by reducing the angular velocity $\omega_i(t)$ of each drive i in accordance with the formula $\omega_i(t) = \sqrt{\omega_{i,0}^2 - \frac{2k_i}{J_i} t}$.

In this case, $\omega_{i,0}$ denotes the angular velocity at the beginning of the deceleration process, J_i denotes the moment of inertia where $J_i = \int \rho_i(\tau) r^2 \, \mathrm{d}\tau$, $\rho_i(\tau)$ denotes the density distribution, r denotes the distance from the axis of rotation, k_i denotes a deceleration capacity of the drive i, $\mathrm{d}\tau$ denotes an infinitesimal element of the volume τ that encompasses the rotating parts of the drive i, and t denotes the time.

In this case, the required deceleration capacity k_i results as $k_i = \frac{J_i \omega_{i,0}}{2t_{\mathrm{br}}}$ if an angular velocity $\omega_{i,0}$ at the beginning of the deceleration process and a time duration t_{br} from the beginning of the deceleration until all the drives are at a standstill are predefined.

The duration t_{br} of the deceleration process is preferably determined by the drive i having the greatest angular momentum $L_i = J_i \omega_{i,0}$.

Brief description of the figures

Patent claims

1. A method for the simultaneous double-side material-removing processing of at least three workpieces between a rotating upper working disk and a rotating lower working disk of a double-side processing apparatus, wherein the workpieces lie in freely movable fashion in a respective opening in a guide cage and are moved by the latter under pressure in a working gap formed between the two working disks, wherein, upon a preselected target thickness of the workpieces being attained, a deceleration process is initiated, during which the angular velocities $\omega_i(t)$ of all the drives i of the upper working disk, of the lower working disk and of the guide cage are reduced to a standstill of the two working disks and of the guide cage, wherein the angular velocities $\omega_i(t)$ of all the drives i are reduced in such a way that, during the deceleration phase, the ratios of all the angular velocities $\omega_i(t)$ to one another as a function of the time t deviate by not more than 10% from the ratios at the instant at which the preselected target thickness is attained.

2. The method as claimed in claim 1, wherein the angular velocities $\omega_i(t)$ of all the drives i are reduced in such a way that, during the deceleration phase, the ratios of all the angular velocities to one another as a function of the time t deviate by not more than 5% from the ratios at the instant at which the preselected target thickness is attained.

3. The method as claimed in either of claims 1 and 2, wherein the working disks are ring-shaped, wherein at least three circular guide cages each having at least one cutout for a workpiece and each having a toothing extending circumferentially on the circumference of the guide cages are used simultaneously, wherein the toothing engages into an outer and an inner drive ring, which are in each case arranged

concentrically with respect to the rotational axis of the working disks, and wherein the two drive rings constitute the drives of the guide cages by means of which the guide cages are moved circumferentially with simultaneous inherent rotation about the rotational axis of the working disks, such that the workpieces describe cycloidal trajectories relative to the two working disks.

4. The method as claimed in either of claims 1 and 2, wherein the working disks are circular and exactly one guide cage is used, which covers the entire area of the working disks and is driven by eccentrically rotating guide rollers arranged on the circumference of the working disks to effect an orbital movement such that in the resting reference system for each workpiece there is a respective stationary area which is completely covered by the workpiece at any time.

5. The method as claimed in any of claims 1 to 4, wherein the angular velocity $\omega_i(t)$ of each drive i is reduced in accordance with $\omega_i(t) = \omega_{i,0} - {}^{k_i}\!/_{J_i}\, t$, wherein $\omega_{i,0}$ denotes the angular velocity at the beginning of the deceleration process, J_i denotes the moment of inertia where $J_i = \int \rho_i(\tau) r^2 \, \mathrm{d}\tau$, $\rho_i(\tau)$ denotes the density distribution, r denotes the distance from the axis of rotation, k_i denotes a deceleration capacity of the drive i, $\mathrm{d}\tau$ denotes an infinitesimal element of the volume τ that encompasses the rotating parts of the drive i, and t denotes the time.

6. The method as claimed in any of claims 1 to 3, wherein the magnitude of the change in the angular velocity $\omega_i(t)$ of each drive i per unit time increases in the course of the deceleration process.

7. The method as claimed in claim 6, wherein the angular velocity $\omega_i(t)$ of each drive i is reduced in accordance with $\omega_i(t) = \sqrt{\omega_{i,0}^2 - \frac{2k_i}{J_i} t}$, wherein $\omega_{i,0}$ denotes the angular velocity at the

beginning of the deceleration process, J_i denotes the moment of inertia where $J_i = \int \rho_i(\tau) r^2 \, \mathrm{d}\tau$, $\rho_i(\tau)$ denotes the density distribution, r denotes the distance from the axis of rotation, k_i denotes a deceleration capacity of the drive i, $\mathrm{d}\tau$ denotes an infinitesimal element of the volume τ that encompasses the rotating parts of the drive i, and t denotes the time.

8. The method as claimed in any of claims 1 to 7, wherein the duration t_{br} of the deceleration process is determined by the drive i with the greatest angular momentum $L_i = J_i \omega_{i,0}$, wherein $\omega_{i,0}$ denotes the angular velocity at the beginning of the deceleration process, $J_i = \int \rho_i(\tau) r^2 \, \mathrm{d}\tau$ denotes the moment of inertia, $\rho_i(\tau)$ denotes the density distribution, r denotes the distance from the axis of rotation, $\mathrm{d}\tau$ denotes an infinitesimal element of the volume τ that encompasses the rotating parts of the drive i, and t denotes the time.

9. The method as claimed in any of claims 1 to 8, wherein the pressure exerted on the workpieces by the two working disks is reduced during the deceleration process.

10. The method as claimed in claim 9, wherein the pressure at the end of the deceleration process is greater than zero.

11. The method as claimed in any of claims 1 to 10, wherein each working disk respectively carries a working layer containing fixedly bonded abrasive which, through contact with the workpieces, brings about material removal from the workpieces by grinding.

【Claims】

1. A method for the simultaneous double-side material-removing processing of at least three workpieces between a rotating upper working disk and a rotating lower working disk of a double-side processing apparatus, wherein the workpieces lie in freely movable fashion in a respective opening in a guide cage and are moved by the latter under pressure in a working gap formed between the two working disks, wherein, upon a preselected target thickness of the workpieces being attained, a deceleration process is initiated, during which the angular velocities $\omega_i(t)$ of all the drives i of the upper working disk, of the lower working disk and of the guide cage are reduced to a standstill of the two working disks and of the guide cage, wherein the reducing being carried out such that all ratios $\frac{\omega_{i,ACTUAL}(t)}{\omega_{j,ACTUAL}(t)}, i \neq j$ of the angular velocities $\omega_{i,ACTUAL}(t)$ deviate by no more than 10 % from the initial ratios $\frac{\omega_i(t=0)}{\omega_j(t=0)}, i \neq j$, of the angular velocities $\omega_i(t=0)$ corresponding to when the preselected target thickness was attained ($t=0$).

2. The method as claimed in claim 1, wherein the reducing being carried out such that all ratios $\frac{\omega_{i,ACTUAL}(t)}{\omega_{j,ACTUAL}(t)}, i \neq j$ of the angular velocities $\omega_{i,ACTUAL}(t)$ deviate by no more than 5 % from the initial ratios $\frac{\omega_i(t=0)}{\omega_j(t=0)}, i \neq j$, of the angular velocities $\omega_i(t=0)$ corresponding to when the preselected target thickness was attained ($t=0$).

3. The method as claimed in either of claims 1 and 2, wherein the working disks are ring-shaped, wherein at least three circular guide cages each having at least one cutout for a workpiece and each having a toothing extending circumferentially on the circumference of the guide cages are used simultaneously, wherein the toothing engages into an outer

and an inner drive ring, which are in each case arranged concentrically with respect to the rotational axis of the working disks, and wherein the two drive rings constitute the drives of the guide cages by means of which the guide cages are moved circumferentially with simultaneous inherent rotation about the rotational axis of the working disks, such that the workpieces describe cycloidal trajectories relative to the two working disks.

4. The method as claimed in either of claims 1 and 2, wherein the working disks are circular and exactly one guide cage is used, which covers the entire area of the working disks and is driven by eccentrically rotating guide rollers arranged on the circumference of the working disks to effect an orbital movement such that in the resting reference system for each workpiece there is a respective stationary area which is completely covered by the workpiece at any time.

5. The method as claimed in either of claims 1 and 2, wherein the angular velocity $\omega_i(t)$ of each drive i is reduced in accordance with $\omega_i(t) = \omega_{i,0} - \frac{K_i}{J_i \omega_{i,o}} t$, wherein $\omega_{i,0}$ denotes the angular velocity at the beginning of the deceleration process, J_i denotes the moment of inertia where $J_i = \int \rho_i(\tau) r^2 \, \mathrm{d}\tau$, $\rho_i(\tau)$ denotes the density distribution, r denotes the distance from the axis of rotation, k_i denotes a deceleration capacity of the drive i, $\mathrm{d}\tau$ denotes an infinitesimal element of the volume τ that encompasses the rotating parts of the drive i, and t denotes the time.

6. The method as claimed in either of claims 1 and 2, wherein the absolute value of the magnitude of the change in the angular velocity $\omega_i(t)$ of each drive i per unit time increases in the course of the deceleration process.

7. The method as claimed in claim 6, wherein the angular velocity $\omega_i(t)$ of each drive i is reduced in accordance with $\omega_i(t)=\sqrt{\omega_{i,0}^2-\frac{2k_i}{J_i}t}$, wherein $\omega_{i,0}$ denotes the angular velocity at the beginning of the deceleration process, J_i denotes the moment of inertia where $J_i=\int\rho_i(\tau)r^2\,\mathrm{d}\tau$, $\rho_i(\tau)$ denotes the density distribution, r denotes the distance from the axis of rotation, k_i denotes a deceleration capacity of the drive i, $\mathrm{d}\tau$ denotes an infinitesimal element of the volume τ that encompasses the rotating parts of the drive i, and t denotes the time.

8. The method as claimed in either of claims 1 and 2, wherein the duration t_{br} of the deceleration process is determined by the drive i with the greatest angular momentum $L_i=J_i\omega_{i,0}$, wherein $\omega_{i,0}$ denotes the angular velocity at the beginning of the deceleration process, $J_i=\int\rho_i(\tau)r^2\,\mathrm{d}\tau$ denotes the moment of inertia, $\rho_i(\tau)$ denotes the density distribution, r denotes the distance from the axis of rotation, $\mathrm{d}\tau$ denotes an infinitesimal element of the volume τ that encompasses the rotating parts of the drive i, and t denotes the time.

9. The method as claimed in either of claims 1 and 2, wherein the pressure exerted on the workpieces by the two working disks is reduced during the deceleration process.

10. The method as claimed in claim 9, wherein the pressure at the end of the deceleration process is greater than zero.

11. The method as claimed in either of claims 1 and 2, wherein each working disk respectively carries a working layer containing fixedly bonded abrasive which, through contact with the workpieces, brings about material removal from the workpieces by grinding.