FIVE-BAR MECHANISM WITH DYNAMIC BALANCING MEANS AND METHOD FOR DYNAMICALLY BALANCING A FIVE-BAR MECHANISM

The invention relates to a device for manipulating objects, more particularly for manipulating electronic components. The invention also relates to a method for manipulating objects, more particularly manipulating electronic components, using such a device.

For the manipulation of objects, such as more particularly gripping, displacing and setting down electronic components, use is made of various types of manipulator. Examples hereof are a carriage displaceable along right-angle guides, and a robot arm. Such manipulators can function with a high positional accuracy but have the drawback that the acceleration at which they can operate is limited. If functioning with great accuracy is required, they must furthermore be provided with a heavy frame to prevent undesired movement of the frame as a result of the reactive forces and reactive moments associated with the accelerations of the manipulator and machine parts assembled therewith. Because of the increasing production speeds in the industry where electronic components are manufactured and/or processed, the existing manipulators increasingly form a limitation to further optimization of such processes.

The object of the present invention is to provide a device and a method for manipulating objects, more particularly manipulating electronic components, with which operation can take place at high speeds without, or at least with fewer of, the drawbacks of the prior art.

The present invention provides for this purpose a device for manipulating objects, more particularly manipulating electronic components, comprising: a rod mechanism which is provided with at least two master rods with a slave rod pivotally engaging on each of the master rods, which slave rods are mutually connected at a distance from the master rods, two actuators engaging on each of the master rods, which actuators can be operated independently of each other, and a balancing mechanism for compensating dynamic forces during movement of the rod mechanism. A rod mechanism is also referred to as a rod assembly. A position defined by the slave rods is fully controlled by means of actuating at least a single degree of freedom of each of the master rods of the mechanism. The actuators (which can also be referred to as drive mechanisms) can be

embodied in simple manner because they only have to provide a single freedom of movement and can moreover be connected to the fixed world. The dynamic mass of the device can thus be kept very limited; the actuators do not have to form part of the dynamic mass. A small dynamic mass reduces the forces which can bring about vibrations in the frame. Particularly in the displacement of electronic components such as semiconductors, the mass of the products for displacing is also extremely small, which makes it possible to adjust the balancing mechanism to the inertia of the rod mechanism. It is precisely in such an application, in which the load-bearing capacity of the manipulator can remain very low, that it therefore becomes possible to operate with (very) high accelerations. It is precisely the present manipulator which makes this possible without very expensive measures being necessary for this purpose. The presence of a balancing mechanism for the force compensation also prevents a substantial resulting reactive force being exerted on the vicinity (fixed world of which the drive means form part) by the drive means. This has the result that the frame of a manipulator and the anchoring of the frame to the fixed world can be embodied relatively easily without creating vibration.

The balancing mechanism for compensation of dynamic forces can be provided with a force balancing which comprises counter-bodies (counterweights) assembled with the rod mechanism. Such a construction can be very simple and does not require complex control; the mechanical coupling of the manipulator and the associated counter-bodies (or optionally a single counter-body) provides for a good generation of the desired compensating balancing force(s). Another possibility is for the balancing mechanism for the force compensation to comprise at least one body which is displaceable separately of the rod mechanism and which is operated by means of a compensating drive. The control of such a balancing mechanism will usually take place by means of an electronic control. Such an electronically controlled balancing mechanism can be placed at a distance from the rod mechanism, which provides a greater freedom in construction. It is furthermore no longer necessary for the balancing mechanism to form part of the dynamic mass, resulting in an extremely light construction of the rod assembly. It is noted that there are of course also possibilities for combining an electronically controlled balancing mechanism with force compensation provided with counter-bodies assembled with the rod mechanism. Finally, it is noted that the dynamic compensation of force can be carried out in all directions (with 3 degrees of freedom), but it is also

possible to opt for compensation of force which can only be realized in a limited number of directions, i.e. with less than 3 degrees of freedom. Using such limited compensation of force the most disruptive reactive force(s) can be at least partly compensated, while another reactive force or other reactive forces is/are not compensated.

In practice the slave rods will carry a processing element. Such a processing element can for instance consist of a head with a gripper which can be controlled mechanically or pneumatically, a camera, various types of tool, a coupling part for co-action with diverse processing elements, and so forth. The slave rods can be directly connected to each other, or connected via another element such as a coupling part.

The actuators engaging on the two master rods can generate rotating drive movements, for instance by means of two independently operating servomotors. For a compact assembly it therefore becomes possible to place the rotation axes of the rotating actuators coaxially, i.e. these rotation axes lie mutually in line. On the other hand it is also possible for the actuators engaging on the two master rods to generate linear drive movements such that the master rods can move reciprocally (such as for instance in oscillating or intermittent manner). The linear actuators can for instance be disposed parallel to each other, for instance in the form of a parallel arrangement of for instance linear motors. Alternatively, it is also possible to envisage the master rods being engaged by a drive rod which is driven rotatingly on one side and which converts a rotating movement into a linear movement. It is possible to opt for a specific type of drive depending on the conditions (such as overall space available, energy consumption, required accuracy and so forth). Finally, it is noted that it is also possible for one of the master rods to be driven rotatingly and another master rod to be driven with a linear movement.

In addition, it is an extra advantage if the device also comprises a balancing mechanism for moment compensation (torque compensation) of the reactive moment (torque) generated by displacement of the rod assembly. Using such an additional balancing mechanism the manipulator can be dynamically balanced to an even greater extent, which even provides the possibility of the complete absence (at least theoretically) of a resultant reactive force and a resultant reactive moment, whereby the manipulator will

(at least theoretically) make no contact whatever with its vicinity. The above described advantages in respect of the advantages of a balancing mechanism for force compensation therefore also apply in respect of ending resultant moments. In respect of the dynamic moment compensation it is also noted that the moment compensation can be realized in all directions (with 3 degrees of freedom), although it is also possible to opt for realizing the moment compensation in only a limited number of directions, i.e. with fewer than 3 degrees of freedom. Using such limited moment compensation the most disruptive moment(s) can be at least partly compensated, while another moment or other moments is/are not compensated.

The balancing mechanism for moment compensation can be embodied such that it comprises at least one counter-rotating body assembled with the rod mechanism. Conversely, it is also possible for the balancing mechanism for moment compensation to comprise at least one body which is displaceable separately of the rod mechanism and which is operated by means of a compensating drive. As described above, this second variant requires an electronic control, although this latter can also be placed at a distance from the rod mechanism. The advantage of an electric control is once again that it results in a relatively light construction of the rod assembly and in a limitation of the total inertia.

Further (synergy) advantages can be achieved if the balancing mechanism for moment compensation is assembled with the balancing mechanism for force compensation.

The present invention also provides a method for manipulating objects, more particularly manipulating electronic components, using a device according to any of the foregoing claims and comprising the processing steps of: A) independently controlling two actuators engaging on the master rods of a rod mechanism, and B) at least partly compensating reactive forces (and/or reactive moments) generated as a result of the displacement of the rod mechanism by means of at least one balancing mechanism. For the advantages of such a method reference is made to the above stated advantages in respect of the balancing mechanisms in accordance with the device according to the present invention.

It is also possible in this method for the operation of the balancing mechanism to be

coupled mechanically to the rod assembly, or for the operation of the balancing mechanism to be controlled electrically. Electric control is possible on the basis of controlling the actuators engaging on the rod mechanism and/or of sensors arranged for this purpose.

The present invention will be further elucidated on the basis of the non-limitative exemplary embodiments shown in the following figures. Herein:
figure 1A shows a schematic view of a rod assembly as component of the device according to the present invention,
figure 1B shows a schematic view of an alternative embodiment variant of a rod assembly as component of the device according to the present invention,
figure 1C shows a schematic view of a second embodiment variant of a rod assembly as component of the device according to the present invention,
figure 2 is a schematic view of a manipulation device according to the present invention provided with a balancing mechanism for force compensation,
figure 3 is a schematic view of an alternative embodiment variant of a manipulation device according to the present invention provided with a balancing mechanism for force compensation and a balancing mechanism for moment compensation, and
figure 4 is a schematic view of a second alternative embodiment variant of a manipulation device according to the present invention provided with an electronically controlled balancing mechanism.

Figure 1A shows a rod mechanism 1 with two master rods 2, 3 which can be rotated by means of servomotors 4, 5 (see arrows R_1 and R_2). Servomotors 4, 5 are connected to the fixed world via motor supports 6, 7. On each of the master rods 2, 3 engage the respective slave rods 8, 9. Master rod 2 and slave rod 8 are mutually connected in freely pivotable manner via a hinge 10. Likewise, master rod 3 and slave rod 9 are mutually connected in freely pivotable manner via a hinge 11. The position of a head 12 carried by slave rods 8, 9 can be fully controlled by means of controlled driving of servomotors 4, 5.

Figure 1B shows a rod mechanism 20 with two master rods 21, 22 which are only displaceable in longitudinal direction (see arrows L_1 and L_2) by means of linear drives 23, 24. These linear drives 23, 24 are connected to the fixed world via supports 25, 26.

Master rods 21, 22 are connected to slave rods 29, 30 via hinges 27, 28. Slave rods 29, 30 carry a head 31, the position of which is determined as a result of operating linear drives 23, 24.

Figure 1C shows a rod mechanism 40 which greatly resembles rod mechanism 1 as shown in figure 1A. Master rods 41, 42 are driven by two separate motors, of which only one motor 43 can be seen. This is the result of the fact that the motors are placed mutually in line such that only the upper motor 43 is visible in the shown view. For a further description of this rod mechanism 40 reference is made to the description relating to figure 1A.

Figure 2 shows a schematically represented manipulation device 50 according to the present invention. Device 50 is provided with two master rods 51, 52, which master rods 51, 52 are provided with weights 53, 54 which form a balancing mechanism for force compensation. Reference is made to figures 1A-1C for a further description of this manipulation device 50.

Figure 3 shows a schematically represented manipulation device 60 according to the present invention with master rods 61, 62 which are provided with weights 63, 64, which form a balancing mechanism for force compensation. Manipulation device 60 is however also provided with a balancing mechanism for moment compensation. This balancing mechanism for moment compensation is formed by two rotatable weights 65, 66 which, when rod mechanism 60 is rotated, rotate in an opposite direction as a result of two activating wheels 67, 68 which are connected to master rods 61, 62 and which engage on an inner side of a ring 69 in stationary position. The rod mechanism can thus be compensated in fully dynamic manner such that no (or practically no) resultant forces are exerted by a support 70 on the fixed world as a result of movements of mechanism 60.

Finally, figure 4 shows a rod assembly 80 corresponding to the rod assembly shown in figure 1C. The drives 81 are however now connected to a central control unit 84 via signal lines 82, 83. Central control unit 84 calculates the desired compensation forces and moments and then controls a separate compensation unit 86 by means of an output signal line 85. This compensation unit 86 is connected to the same fixed world 87 as

that to which rod assembly 80 is connected. It is thus possible to achieve that the resultant of the forces exerted by rod assembly 80 and compensation unit 86 is zero (or very small). Compensation unit 86 can be provided with complete compensation means (with mass which can be translated in three directions and rotated in three directions, i.e. with 6 degrees of freedom), although it is also possible to opt for embodying the compensation means with only a limited number of degrees of freedom, i.e. with less than 6 degrees of freedom. Using such limited compensation means the most disruptive reactive force(s) and/or reactive moment(s) can be compensated while less disruptive reactive force(s) and/or reactive moment(s) are not compensated. It will be apparent that compensation means with less than 6 degrees of freedom are simpler and cheaper than complete compensation means with 6 degrees of freedom.

Claims

1. Device for manipulating objects, more particularly manipulating electronic components, comprising:
- a rod mechanism which is provided with at least two master rods with a slave rod pivotally engaging on each of the master rods, which slave rods are mutually connected at a distance from the master rods,
- two actuators engaging on each of the master rods, which actuators can be operated independently of each other, and
- a balancing mechanism for compensating dynamic forces during movement of the rod mechanism.

2. Device as claimed in claim 1, characterized in that the balancing mechanism for force compensation comprises counter-bodies assembled with the rod mechanism.

3. Device as claimed in claim 1 or 2, characterized in that the balancing mechanism for the force compensation comprises at least one body which is displaceable separately of the rod mechanism and which is operated by means of a compensating drive.

4. Device as claimed in any of the foregoing claims, characterized in that the slave rods carry a processing element.

5. Device as claimed in any of the foregoing claims, characterized in that the actuators engaging on the two master rods generate rotating drive movements.

6. Device as claimed in claim 5, characterized in that the rotation axes of the rotating actuators are placed in parallel, preferably coaxially.

7. Device as claimed in any of the claims 1-5, characterized in that the actuators engaging on the two master rods generate linear drive movements.

8. Device as claimed in claim 7, characterized in that the linear actuators are disposed parallel to each other.

9. Device as claimed in any of the foregoing claims, characterized in that the device also comprises a balancing mechanism for moment compensation of the moment generated by displacement of the rod assembly.

10. Device as claimed in claim 9, characterized in that the balancing mechanism for moment compensation comprises at least one counter-rotating body assembled with the rod mechanism.

11. Device as claimed in claim 9 or 10, characterized in that the balancing mechanism for moment compensation comprises at least one body which is displaceable separately of the rod mechanism and which is operated by means of a compensating drive.

12. Device as claimed in any of the claims 9-11, characterized in that the balancing mechanism for moment compensation is assembled with the balancing mechanism for force compensation.

13. Method for manipulating objects, more particularly manipulating electronic components, using a device as claimed in any of the foregoing claims, comprising the processing steps of:
A) independently controlling two actuators engaging on the master rods of a rod mechanism, and
B) at least partly compensating reactive forces generated as a result of the displacement of the rod mechanism by means of at least one balancing mechanism.

14. Method as claimed in claim 13, characterized in that the operation of the balancing mechanism is coupled mechanically to the rod assembly.

15. Method as claimed in claim 13 or 14, characterized in that the operation of the balancing mechanism is controlled electrically.

16. Method as claimed in any of the claims 13-15, characterized in that the operation of the balancing mechanism is partly coupled mechanically to the rod assembly and partly controlled electrically.