

A module for selectively attaching to a rotatable turret and a method of determining the force applied to a component

Field of the invention

[0001] The present invention concerns a module for selectively attaching to a rotatable turret, wherein the module comprise a force sensor which can measure force applied to a component as it is delivered onto a surface; and a method of determining the force applied to a component using said module.

Description of related art

[0002] Component handling assemblies used in the art typically comprise a rotatable turret which comprises a plurality of component handling heads which can each hold a respective component by vacuum. Each component handling head can be moved to deliver a component onto a surface (e.g. to deliver a component onto a surface of a nest of a testing station or processing station located at the periphery of the turret). When the component handling head delivers a component onto a surface forces are experienced by the component, such as an impact force and a compression force applied to the component by the component handling head, when the component impacts the surface. The forces experienced by the component can damage the component if they are too large; accordingly it is preferable that these forces be measured prior to using the component handling assembly to handle components.

[0003] In existing techniques which are used in the art to measure the forces applied to a component as it is delivered, by a component handling head, directly onto a surface of a force sensor; the force sensor measures force as the component impacts the surface of the force sensor and thereafter. However the surface of the force sensor is not identical to the surface on which the component will be delivered onto when the component handling assembly is in use in the field; for example the surface of the force sensor is typically more rigid than a surface of a nest of a

testing station or processing station onto which the component is to be delivered when the component handling assembly is in use in the field, and/or the geometry of the surface of the force sensor is different to the geometry of the surface of a nest of a testing station or processing station
5 onto which the component is to be delivered when the component handling assembly is in use in the field. Therefore the measured forces do not accurately represent the forces experienced by the component when the component handling assembly is in use in the field; critically the forces do typically are less than the forces experienced by the component when
10 the component handling assembly is in use in the field, and as a result there remains a high risk that component become damaged when the component handling assembly is in use in the field.

[0004] It is an aim of the present invention to obviate or mitigate the disadvantages associated with existing assemblies and techniques in the art.

15 Brief summary of the invention

[0005] According to the invention, these aims are achieved by means of a module having the features recited in independent claim 1. The dependent claims recite favorable features of the module.

[0006] There is further provided a method of determining the force
20 applied to a component using said module. As will be described in more detail, this method can in turn be used to calibrate actuators in a component handling assembly.

Brief Description of the Drawings

[0007] The invention will be better understood with the aid of the
25 description of embodiments, which given by way of example only, and illustrated with figures, in which:

Figure 1a provides a perspective view of a module according to an embodiment of the present invention, with a longitudinal

section view of the free end of the module; Figure 1b provides a longitudinal section view of the module;

5 Figure 2 provides a perspective view of part of a component handling assembly 200, and in particular shows a rotatable turret having a plurality of radial arms, and the module of Figures 1a and 1b, is provided on the turret at a position which is otherwise occupied by a radial arm;

10 Figure 3b is a graph representing the position of the second end of the tip member of the module, as a component which is held by vacuum on the second end of the time member, is moved onto a surface; Figure 3a provides an example of an output signal which is output from a signal analyzer device which outputs a signal, which is representative of the force sensed by the force sensor in the module as a component which is held by vacuum on
15 the second end of the time member, is moved onto a surface;

Figures 4a-4d show different conditions which can occur in a component handling assembly, which can be simulated, and subsequently used when performing a method according to an embodiment of the present invention.

20 Detailed Description of possible embodiments of the Invention

[0008] Figure 1a provides a perspective view of a module 1, with a longitudinal section view of the free end of the module 1, for selectively attaching to a rotatable turret, according to an embodiment of the present invention. Figure 1b provides a longitudinal section view of the module 1.

25 **[0009]** Referring to Figures 1a and 1b, the module 1 comprises an arm 2 which comprises a first end 2a which can be fixed to a rotatable turret, and a second free end 2b. The arm 2 further comprises a means to adjust the position of the second free end 2b of the arm 2; for example the arm 2 comprises a first screw member 102a which can be used to move the second

free end 2b of the arm along a first axis (e.g. x-axis) and a second screw member 102b which can be used to move the second free end 2b of the arm along a second axis, which is perpendicular to the first axis (e.g. y-axis).

- [0010]** The module 1 further comprises a tip holder 3 which is
5 configured such that it can selectively hold a tip member 4. In the module 1 illustrated in Figures 1a and 1b the tip holder 3 is configured to hold a tip member 4; however it should be understood that the tip member 4 is not an essential feature of the module 1; the tip members 4 may require regular replacement and could be regarded as being disposable due to
10 their short life-span compared to the life span of the other features of the module 1. The tip member 4 comprises a first end 4c which is held by the tip holder 3, and second, opposite, free end 4b. The tip holder 3 comprises a socket 3d which can receive a first end 4c of the tip member 4. In this example the tip member 4 is tapered in the direction toward the second
15 free end 4b (however it is not essential that the tip member 4 be tapered). The tip member 4 is tubular defining an inner volume 4a; the inner volume 4a of the tip member 4 defining a channel 4a in which a vacuum can be provided; the vacuum provided in the inner volume 4a of the tip member 4 is used to hold a component 5 on a free end 4b of tip member 4.
- 20 **[0011]** The first end 4c of the tip member 4 is held in the socket 3c of the tip holder 3. It should be understood that when the first end 4c of the tip member 4 is held in the socket 3c of the tip holder 3 then the socket 3c of the tip holder 3 is in fluid communication with the inner volume 4a of the tip member 4.
- 25 **[0012]** It should be understood that the tip holder 3 could be configured to hold the tip member 4 using any suitable means. In the example illustrated in Figure 1, the module 1 comprises a clamping member 15; the clamping member 15 may be selectively screwed into the tip holder 3 so as to clamp the tip member 4 between a first end 15a of the clamping
30 member 15 and an inner wall 3b (which is located opposite to the first end 15a of the clamping member 15) of the tip holder 3. When the tip member 4 needs to be replaced the clamping member 15 may be unscrewed from

the tip holder 3 so as to release the tip member 4; when a replacement tip holder 3 has been inserted into the tip holder 3 the clamping member 15 may be screwed into the tip holder 3 again so as to clamp the new tip member 4 between the clamping member 15 and an inner wall 3b of the tip holder 3. In this example the clamping member 15 is defined by a male screw member 15 which can be selectively screwed in, or unscrewed from, a threaded recess 15b which is defined in the tip holder 3; however it should be understood that the clamping member 15 may take any suitable form.

[0013] The tip holder 3 further comprises an inlet 6 which can be selectively fluidly connected to a vacuum generator. In the module 1 illustrated in Figures 1a and 1b the inlet 6 is fluidly connected to a vacuum generator 7 via a conduit 8; said conduit 8 is connected between the inlet 6 in the tip holder 3 and the vacuum generator 7. Said inlet 6 is fluidly connected to the socket 3c of tip holder 3, so that when the vacuum generator 7 is operated to generate a vacuum, then a vacuum provided in the inner volume 4a of the tip member 4 which is held in the socket 3c of the tip holder; said vacuum which is provided in the inner volume 4a of the tip member 4 can be used to hold a component 5 on a free end 4b of tip member 4.

[0014] The module 1 further comprises a shaft member 9 which is arranged such that it can be moved linearly along an axis 19a which is parallel to a longitudinal axis of said shaft member 9. The module 1 further comprises a guide member 30 which guides the linear movement of the shaft member 9 along the axis 19a; in this example the guide member 30 comprises a ball cage 30, however it should be understood that the guide member 30 may take any suitable form. The shaft 9 can be selectively moved through the ball cage 30, along the axis 19a; the ball cage 30 restrains the movement of the shaft 9 to along the axis 19a.

[0015] The shaft member 9 comprises a first end 9a and a second, opposite, end, 9b. The first end 9a of the shaft member 9 can cooperate with an actuator (not shown; in this embodiment the actuator does not form part of the module 1; in another embodiment the actuator may form

part of the module 1); the actuator can selectively apply a force to the first end 9a of the shaft member 9 to move the shaft member 9 linearly along said axis 19a, thus moving the component 5, which is held by vacuum on second end 4b of the tip member 4, downwards along the axis 19a. The

5 module 1 further comprises a biasing means 130 which biases the shaft member 9 towards its starting position (i.e. the position which the shaft member 9 occupied before the actuator applies a force to the first end 9a of the shaft member 9 to move the shaft member 9 linearly along said axis 19a). In this example the biasing means 130 comprises a spring blade 130

10 which is attached at a first end 130a to the first end 9a of the shaft member 9 and is attached at a second, opposite, end 130b to the arm 2. When the actuator applies a force to the first end 9a of the shaft member 9 to move the shaft member 9 linearly along said axis 19a, the first end 130a of the spring blade 130 is moved in a direction towards the second, opposite, end

15 130b of the spring blade 130; in other words the spring blade 130 is moved into a flexed state (the force of the actuator forcing the spring blade 130 into said flexed state). When the actuator releases the force it applies to the first end 9a of the shaft member 9, then the force which was maintaining the spring blade 130 in its flexed state is released and the

20 spring blade 130 elastically recoils; as the spring blade 130 elastically recoils the first end 130a of the spring blade 130 moves in a direction away from the second, opposite, end 130b of the spring blade 130; as the first end 130a of the spring blade 130 moves in a direction away from the second, opposite, end 130b of the spring blade 130, it applies a force to the first

25 end 9a of the shaft member 9 which moves the shaft member 9 linearly along said axis 19a, in a direction which is opposite to the direction in which the actuator moved the shaft member 9, so that the first end 9a of the shaft member 9 is moved back to its original position (i.e. the position which the first end 9a of the shaft member 9 occupied before the actuator

30 applied a force to the first end 9a of the shaft member 9).

[0016] The actuator can selectively apply a plurality of different amounts of predefined forces to the first end 9a of the shaft member 9, accordingly the actuator can move the shaft member 9, at a corresponding plurality of predefined speeds, linearly, along said axis 19a since the speed

at which the shaft member 9 moves along the axis 19a is directly proportional to the force which the actuator applies to the first end 9a of the shaft member 9. The predefined force which the actuator applies to the first end 9a of the shaft member 9, and thus the speed at which the
5 actuator moves shaft member 9, linearly, along said axis 19a, (and thus the speed at which the component 5 is moved along the axis 19a) is controlled by a controller 20.

[0017] The module 1 further comprises a force sensor 12 which is located between said tip holder 3 and the second end 9b of said shaft member 9.
10 The force sensor 12 comprises a first attachment means 12a which attaches the force sensor to the second end 9b of the shaft member 9, and a second attachment means 12b which attaches the force sensor 12 to the tip holder 3. It should be understood that the first and second attachment means 12a,b can take any suitable form; in this example the first attachment
15 means 12a is a threaded female member (e.g. a threaded recess) which can receive a threaded male member (e.g. a threaded screw member) provided at the second end 9b of the shaft member 9, and the second attachment means 12b is a threaded female member (e.g. a threaded recess) which can receive a threaded male member (e.g. a threaded screw member) provided
20 on the tip holder 3.

[0018] The force sensor 12 is configured to measure a compression force between the second end 9b of the shaft member 9, and the tip holder 3; the compression force between the second end 9b of the shaft member 9 is directly proportional to (and substantially equal to) the force applied by
25 the tip member 4 to component 5 when, for example, the component 5 is placed onto a surface, such as the surface of a nest of a processing station (i.e. the component 5 is compressed by the tip member 4 against said surface).

[0019] The controller 20 is operatively connected to the force sensor 12.
30 The controller 20 is configured to stop the actuator from applying a force to the first end 9a of the shaft member 9 if the force sensor 12 measures a force which is equal to, or greater than, a predefined threshold force.

[0020] In order to deliver the component 5 to a surface, such as the surface of a nest of a processing station, the module is positioned so that the component 5, which is held by the tip member 4, is aligned above said surface. The controller 12 then initiates the actuator to apply a force to the first end 9a of the shaft member 9 to cause the shaft member to move from its initial position, along the axis 19a, so that the component 5 is moved towards the surface.

[0021] The total distance which the component 5 is moved, from its initial position to the position wherein the component 5 contacts the surface, will be referred to hereafter as the total stroke distance. Most preferable the controller 20 is configured to cause the actuator to apply a first predefined force to the first end 9a of the shaft member 9, over a first predefined section of the total stroke distance, and to cause the actuator to apply a second predefined force to the first end 9a of the shaft member 9, over a second predefined section of the total stroke distance. In an embodiment the controller 20 may be configured to cause the actuator to apply a force to the first end 9a of the shaft member 9, and to cause the actuator to decrease the force it applies to the first end 9a of the shaft member 9 as the component 5, which is held by the tip member 4, is approaches said surface. For example the controller 20 may be configured to cause the actuator to apply a first predefined force to the first end 9a of the shaft member 9, over the first predefined section of the total stroke distance, so that the component is moved at a first speed over said first predefined section of the total stroke distance; and to cause the actuator to apply a second predefined force, which is less than the first predefined force, to the first end 9a of the shaft member 9, over the second predefined section of the total stroke distance, so that the component is moved at a second speed, which is slower than the first speed, over said second predefined section of the total stroke distance.

[0022] The module 1 further comprises a height adjustment mechanism 110 which can be used to set the initial position of the shaft member 9. The height adjustment mechanism is more clearly illustrated in Figure 1c. In this particular embodiment the height adjustment mechanism 110 comprises a

screw member 112 which is arranged to screw into a fixed part 113 of the arm 2 , along a direction which is parallel to the axis 19a along which the shaft 9 can move, and a intermediary member 111 which connects the screw member 112 to the shaft 9, so that when the screw member is
5 screwed into the fixed part 113 of the arm 2 the first end 9a of the shaft 9 is moved to a lower initial position, and when the screw member 112 is screwed out of the fixed part 113 of the arm 2 the first end 9a of the shaft 9 is moved to a higher initial position. Thus using the height adjustment mechanism 110 the shaft member 9 can be set to have any
10 desired/predefined initial position. The initial position of the shaft member 9 may be set to a higher position, thus increasing the total stroke distance; or the initial position of the shaft member 9 may be set to a lower position thus decreasing the total stroke distance.

[0023] Figure 2 provides a perspective view of part of a component
15 handling assembly 200. The component handling assembly 200 comprises a rotatable turret 203 having a plurality of radial arms 214; in the example shown in Figure 2 one of the radial arms 214a has been removed (temporality) from the turret 203 and the module 1 has been attached to the turret 203 in its place; in other words the module 1 is provided on the
20 turret 203 at a position which is otherwise occupied by a radial arm 214.

[0024] In this example each of the plurality of radial arms 214 have the same features. For example, each of the radial arms 214 comprises a component handling head 215 which can hold a respective component 5 by vacuum at a tip 204 of the component handling head 215.

25 **[0025]** Typically, processing and/or test stations are located at the periphery of the turret 203 (however for clarity these processing/test stations are not shown in the figure); during use the turret 203 is iteratively rotated and the component handling head 215 are operated to pick and place the components which they hold from/to the respective
30 processing/test stations so that components are moved consecutively to each of the processing/test station.

- [0026]** Each of the radial arms is similar to the module 1 shown in Figure 1, however they do not comprise any force sensor. For example, similar to the module 1, each component handling head 205 comprises a shaft member 209 having a first end 209a; the shaft member 209 can be moved linearly along an axis 219a which is parallel to a longitudinal axis of said shaft member 209. An actuator can selectively apply a force (either directly or indirectly) to the first end 209a of the shaft member 209 to move the shaft member 209 linearly along an axis 219a, thus moving the component 5, which is held by vacuum on second end 4b of the tip member 4, downwards along the axis 19a. Each component handling head 205 further comprises a guide member which guides the linear movement of the shaft member 209 along the axis 219a; in this example the guide member comprises a ball cage 230, which is preferably identical to the type of ball cage 30 provided in the module 1.
- [0027]** Most preferably, the module 1 is configured so that (e.g. the length of the shaft 9 in the module 1 is such that) the distance between the first end 9a of the shaft member 9 and the second end 4b of the tip member 4, is equal to the distance between the first end 209a of the shaft member 209 and the tip 204 of the component handling head 215. Using the height adjustment mechanism 110 in the module 1, the height of the of the first end 9a of the shaft member 9 can be adjusted to be equal to the height of the first end 209a of the shaft member 209 – this will ensure that that the stroke distance of the module 1 is equal to the stroke distances of each of the radial arms 214.
- [0028]** The assembly 200 further comprises a plurality of actuators; in this example each of the plurality of actuators are the same as one another. All except one of the actuators overlays a respective component handling head 215; and these actuators can selectively apply a force (either directly or indirectly) to the first end 209a of the shaft member 209 of the respective component handling head 215, so as to move the shaft member 209 linearly of that component handling head 215 along the axis 219a, thus moving the component 5, which is held at tip 204 of the component handling head 215 onto a surface located below the component 5 (e.g.

onto the surface of a nest belonging to a test station or processing station). One of the actuators overlays the first end 9a of the shaft member 9 of the module 1; this actuator can selectively apply a force to the first end 9a of the shaft member 9 to move the shaft member 9 linearly along said axis
5 19a, thus moving the component 5, which is held by vacuum on second end 4b of the tip member 4, downwards onto a surface located below the component 5 (e.g. onto the surface of a nest belonging to a test station or processing station). Typically, the location of the plurality of actuators in the assembly 200 is fixed and the turret 203 is rotated iteratively so that the
10 component handling heads 205 and module 1 are moved to below each of the respectively actuators consecutively.

[0029] Importantly the force which the actuators apply to the component handling heads 205 or module 1 dictates the speed at which the component 5 is moved onto said surface; the speed at which the
15 component 5 is moved onto the surface dictates the force which the component handling head 205 or module 1 applies to the component when the component 5 initially impacts said surface. As mentioned in an embodiment of the present invention the controller 20 is configured to cause the actuator to apply a force to the end 9a of the shaft member 9,
20 and to cause the actuator to decrease said force it applies to the first end 9a of the shaft member 9 as the component 5, which is held by the tip member 4, approaches said surface, advantageously this allows the component 5 to be moved speedily to towards the surface (because initially the speed at which the component 5 is moved toward the surface is high
25 due to a high force applied by the actuator to the shaft member 9) without having an high impact force (i.e. force at which the component impacts the surface (because, as the component approaches the surface, the speed at which the component 5 is moved toward the surface is reduced, due to reduction in the force which is applied by the actuator to the shaft member
30 9).

[0030] The duration over which the actuators apply their force will also dictate whether or not the component handling head 205 or module 1

continues to apply force to the component after the component 5 has impacted said surface.

[0031] As will be described in more detail below, the module 1, which has been attached to the turret 203 of the assembly 200, can be used to
5 calibrate the actuators so that they provide a force which is within a predefined range, and/or so that they provide a predefined force, and/or to ensure that they do not apply a force which exceeds a predefined threshold force. Specifically the module 1 can be used to assist in determining
10 actuator parameters of the actuator (such as, for example, the level of current supplied to the actuator; deceleration and acceleration of the actuator; optical encoder tracking error window size; optimal velocity and speed of the actuator, depending on the stroke distance) which applies a force to the first end 9a of the shaft member 9 of the module 1, so that the actuator applies a desired force or applies a force within a desired range;
15 then since all of the actuators in the assembly 200 are the same the other actuators in the assembly can be turned to have said determined parameters so that they each apply said desired force or apply a force within said desired range. Preferably in the present invention, the use of the module 1 to calibrate the actuators in a component handling assembly,
20 begins with determining the force applied by a component handling head on a turret, to a component, when the component handling head is delivering a component onto a surface which is located below the component/component handling head (e.g. onto the surface of a nest belonging to a test station or processing station which is located below the
25 component/component handling head).

[0032] Thus, according to a further aspect of the present invention there is provided a method of determining the force applied by a component handling head, to a component which is held by that component handling head, when the component is delivered onto a surface which is located
30 below the component handling head.

[0033] The method comprises the steps of, providing a module 1 shown in Figures 1a and 1b. If the module 1 is not already provided with a tip

member 4, then insert the first end 4c of the tip member 4 into the socket 3d of the tip holder 3. Screw the clamping member 15 into the tip holder 3 so as to clamp the tip member 4 between the first end 15a of the clamping member 15 and the inner wall 3b (which is located opposite to the first end 5 15a of the clamping member 15) of the tip holder 3.

[0034] Providing a component handling assembly, which comprises a rotatable turret having a plurality of radial arms, each of the radial arms comprising a component handling head which can hold a respective component by vacuum at a tip of the component handling head; and which 10 comprises a plurality of actuators each of which can apply a force to a respective component handling head. Most preferably the component handling assembly further comprises one or more processing stations and/or test stations are located at the periphery of the turret. After providing the component handling assembly, one of the radial arms on the 15 turret is removed and in its place the module 1 is attached to the turret; this results in an assembly 200 shown in Figure 2.

[0035] It should be understood that the aforementioned steps are not essential to the invention; for example, the module 1 could have already been provided with a tip member 4 held in the tip holder 3, and/or, the 20 component handling assembly could already have the module 1 attached to the turret, before beginning the method of the present invention, in which case it would not be necessary to carry out the afore-mentioned steps.

[0036] In the preferred embodiment of this method, the force sensor 12 25 is operatively connected to a signal analyser device which outputs a signal, which is representative of the force sensed by the force sensor 12.

[0037] The second free end 2b of the arm 2 of the module 1 is then aligned into a desired orientation using the first screw member 102a which can be used to move the second free end 2b of the arm along a first axis 30 (e.g. x-axis) and a second screw member 102b which can be used to move the second free end 2b of the arm along a second axis, which is

- perpendicular to the first axis (e.g. y-axis). Most preferably, in order to perform this step the turret is rotated so as to bring the tip member 4 of the module to an alignment station; at the alignment station cameras are used to capture images showing the position of the tip member 4 relative to a reference; the first and second screw members 102a, 102b are adjusted so that second free end 2b of the arm 2 of the module 1 is in an orientation in which the tip member 4 is positioned in a predefined location relative to the reference visible on the images (e.g. the tip member 4 is aligned with the reference visible on the images).
- 10 **[0038]** The module 1 is configured so that the distance between the first end 9a of the shaft member 9 and the second end 4b of the tip member 4, is equal to the distance between the first end 209a of the shaft member 209 and the tip 204 of the component handling heads 215 in the assembly. Using the height adjustment mechanism 110 in the module 1, the height of the of the first end 9a of the shaft member 9 can be adjusted to be equal to the height of the first end 209a of the shaft member 209 – this will ensure that that the stroke distance of the module 1 is equal to the stroke distances of each of the radial arms 214.
- 15 **[0039]** Next a vacuum generator is operated to provide a vacuum in the inner volume 4a of the tip member; and a component 5 is held by vacuum at the free end 4b of tip member 4.
- 20 **[0040]** The turret is then rotated so that the component 5 which is held by vacuum at the free end 4b of tip member 4, is aligned above a surface onto which it is to be placed; most preferably surface is a surface of a nest of one of the processing stations or the surface of a nest of one of the testing station which is located at the periphery of the turret 203.
- 25 **[0041]** The actuator which is above the first end 9a of the shaft member 9 of the module 1 is then operated to apply a force to the first end 9a of the shaft member 9 which moves the shaft member 9 linearly along said axis 19a, thus moving the component 5, which is held by vacuum on second end 4b of the tip member 4, onto said surface.
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[0042] The force which the actuator applies to the first end 9a of the shaft member 9, and thus the speed at which the component 5 is moved onto the surface, is controlled by a controller 20. The controller 20 is operatively connected to the force sensor 12 and is configured to stop the actuator from applying a force to the first end 9a of the shaft member 9 if the force sensor 12 measures a force which is equal to, or greater than, a predefined threshold force (N_{th}).

[0043] The force sensor 12 measures the compression force between the second end 9b of the shaft member 9, and the tip holder 3 at least as the component is being moved towards the surface, as the component impacts the surface, and after the component has impacted the surface. The compression force between the second end 9b of the shaft member 9 is directly proportional to (and substantially equal to) the force applied by the tip member 4 to component 5. The method of the present invention thus includes the step of measuring the force applied to the component when the component impacts the surface (e.g. the surface of a nest), and measuring the force after the component impacts said surface.

[0044] Figure 3b is a graph representing the position of the second end 4b of the tip member 4, as the component 5 is moved onto the surface. Figure 3a provides an example of an output signal which is output from the signal analyser device which outputs a signal, which is representative of the force sensed by the force sensor 12. Specifically, Figure 3a provides the output signal which is output from the signal analyser device when the component 5 is moved onto the surface, and when the second end 4b of the tip member 4 follows the position profile represented in Figure 3b.

[0045] As already mentioned above the actuator in the assembly 200 can apply a plurality of different amounts of predefined forces to the first end 9a of the shaft member 9, accordingly the actuator can move the shaft member 9, at a corresponding plurality of predefined speeds, linearly, along said axis 19a since the speed at which the shaft member 9 moves along the axis 19a is directly proportional to the force which the actuator applies to the first end 9a of the shaft member 9; thus the component 4

may be moved at a plurality of speeds as it is moved towards the surface. The predefined force which the actuator applies to the first end 9a of the shaft member 9, and thus the speed at which the component 4 is moved to the surface, is controlled by a controller 20. For example, referring to Figure 3b, position 'p1' is the initial starting position of the second end 4b of the tip member 4. The controller 20 then initiates the actuator to apply a first force to the first end 9a of the shaft member 9 to cause the shaft member 9 to move along the axis 9a so that the component 5 held on the second end 4b of the tip member 4 is moved, at a first speed, in a direction towards the surface. Once the second end 4b of the tip member 4 reaches a predefined position 'p2' the controller 20 initiates the actuator to apply a second force (which is less than the first force) to the first end 9a of the shaft member 9 to cause the shaft member 9 to move along the axis 9a so that the component 5 held on the second end 4b of the tip member 4 is moved, at a second speed (which is slower than the first speed), in a direction towards the surface. By reducing the speed at position 'p2' the force which is experienced by the component 5 when it impacts the surface is reduced. At position 'p3' the component 5 impacts the surface; however the actuator continues to apply said second force to the first end 9a of the shaft member 9 which causes the component to flex as the second end 4b of the tip member 4 moves to position 'p4'. As the controller 20 sends the necessary control signals to the actuator to cause it to stop applying a force to the first end 9a of the shaft 9, the second end 4b of the tip member 4 moves to position 'p5' as the flexed component 5 recoils.

25 **[0046]** Referring to Figure 3a, before time 't1' the component is being moved towards the surface, and has not yet impacted the surface; thus the compression force on the component 5 is negligible (before time 't1' corresponds to positions 'p1', 'p2' up to just before position 'p3' in the graph shown in Figure 3b). At time 't2' the component impacts the surface; at time 't2' the compression force which is applied by the tip member 4 to the component 5 increases to a maximum (of 7N) which greatly exceeds a predefined threshold force (N_{th}) due to the momentum of the moving tip member 4 (time 't2' corresponds to position 'p3' in the graph shown in Figure 3b); after this momentum subsides (at time 't3') the compression

force which is applied by the tip member 4 to the component 5 reverts to a substantially steady level (just above 4N in this example) as the actuator continues to apply a force to the first end 9a of the shaft 9. Said steady level (just above 4N in this example) is still above the predefined threshold force (N_{th}). At time 't4' the controller 20 has determined that the predefined threshold force (N_{th}) is exceeded, and has sent the necessary control signals to the actuator to cause it to stop applying a force to the first end 9a of the shaft 9; and between time 't4' and 't5' the compression force which is applied by the tip member 4 to the component 5 decreases as the actuator stops applying a force to the first end 9a of the shaft 9 (time 't4' corresponds to position 'p4' in the graph shown in Figure 3b; and time 't5' corresponds to position 'p5' in the graph shown in Figure 3b). It is noted that between time 't3' and 't4' there is a delay caused by the time it takes for the controller 20 determine that the predefined threshold force (N_{th}) is exceeded, sending the necessary control signals to the actuator to cause it to stop applying a force to the first end 9a of the shaft 9, and time it takes for the actuator motor to respond to the control signal which have been sent by the controller 20.

[0047] Thus, from the output signal which is output from the signal analyzer device one can read the force which is applied by the tip member 4 to the component 5 as the component 5 is delivered onto the surface.

[0048] Using this information one can tune the settings/parameters (such as, for example, the level of current supplied to the actuator; deceleration and acceleration of the actuator; optical encoder tracking error window size; optimal velocity and speed of the actuator, depending on the stroke distance) of the actuator to achieve desired forces. For example, figure 3 shows that the compression force which is applied by the tip member 4 to the component 5 increases to a maximum (of 7N) when the component initially impacts the surface; one might for example want to ensure that the force applied to the component never exceeds 5N, in which case the settings/parameters of the actuator could be adjusted so to reduce speed at which the component is moved towards the surface (e.g. the speed at which the component is moved towards the surface could be

reduced by adjusting the actuator so that it applies less force to the first end 9a of the shaft 9, prior to impact of the component on the surface); this will result in the reducing the momentum of the moving tip member 4, and thus will reduce the compression force which is applied by the tip member 4 to the component 5 when the component 5 initially impacts the surface. One may gradually adjust the settings/parameters of the actuator so as to gradually reduce the speed until the force applied the component on impacting the surface does not exceed 5N. Once the settings/parameters of the actuator have been successfully adjusted so that the force applied the component on impacting the surface is below 5N, then those settings/parameters may be recorded; and the settings/parameters of all the other actuators in the assembly 200 may be adjusted to be the same as said recorded settings/parameters, so that the force applied by each of the respective component handling heads 215 to the respective component which it holds, will not exceed 5N.

[0049] In addition, the above mentioned steps may be repeated for different conditions which might occur in the operation of the component handling assembly 200, so as to determine the settings/parameters of the actuator which are necessary to ensure that the force applied the component even if any one or more of these conditions were to occur, still would not exceed a predefined threshold force (i.e. 5N in the aforementioned example). This ultimately results in improved handling of components within the assembly 200 as it reduces the likelihood of components becoming damaged, even if any one or more of these conditions were to occur.

[0050] For example as shown in Figure 4a debris could be provided on the surface on which the component 5 is to be placed so as to simulate a condition wherein the surface on which the component is to be placed has debris. Then the above mentioned steps could be repeated so as to determine the settings/parameters of the actuator necessary to ensure that the force applied to the component on impacting the surface having debris does not exceed a predefined threshold force (i.e. 5N in the aforementioned example).

[0051] In another example illustrated in Figure 4b a first component is already present on surface, as the a second component 5 held on the tip member 4 of the module, is moved to be placed onto the surface (thus the second component 5 impacts the first component which is already present on the surface). This simulates a condition wherein a first component which has been previously placed on the surface has failed to be removed from the surface, and a component handling head attempts to move a second component onto the surface. The above mentioned steps could be repeated so as to determine the settings/parameters of the actuator necessary to ensure that the force applied to the second component on impacting the first component which is already on the surface, does not exceed a predefined threshold force (i.e. 5N in the aforementioned example). Figure 4c illustrates a similar example except the first and second components each have electrical contacts; the electrical contacts on the first component are electrically connected to electrical contacts provided on the surface.

[0052] In yet another example illustrated in Figure 4c the surface on which the component is to be placed is a surface of a nest, and the nest has tapered side walls. In this example the position of the arm 2 of the module is arranged so that the component impacts the a tapered side wall as it is moved by the module 1 towards said surface. This simulates, for example, a condition wherein the component is held in an incorrect orientation on the component handling head 215, or that the component handling head 215 is not correctly orientated so that its tip is not correctly aligned over the nest, and as a result the component will impact a side wall of the nest as the component handling head moves the component towards the surface. The above mentioned steps could be repeated so as to determine the settings/parameters of the actuator necessary to ensure that the force applied to the component does not exceed a predefined threshold force (i.e. 5N in the aforementioned example) even if the component impacts the side wall of a nest.

[0053] In each of the examples illustrated in Figures 4a-4d, even if any of these conditions were to occur

- [0054] Most preferably the settings/parameters of all of the actuators in the assembly 200 are then adjusted to be the same as said recorded settings/parameters, so that even if any of said conditions were to occur at any of the testing or procession stations of the assembly, as any of the
- 5 component handling heads 215 is moving the respective component which it holds onto the surface of a respective testing or procession station, then the force applied to the component will not exceed said predefined threshold force (i.e. 5N in the aforementioned example); as a result few components will become damaged.
- 10 [0055] Thus the method of the present invention may further comprise the step of adjusting the speed at which the component is moved to the surface so that the force applied to the component when the component impacts the surface, is below a predefined threshold force. The method may further include identifying the maximum speed at which the
- 15 component can be moved to the surface without exceeding said predefined threshold force, and then adjusting the setting/parameters of the actuators so that the component is moved to the surface at said maximum speed (or close to said maximum speed) without exceeding said predefined threshold force. The method may further comprise adjusting the setting/parameters
- 20 of all of the actuators in the assembly to be the same at those indentified as enabling the component to be moved to the surface at said maximum speed (or close to said maximum speed) without exceeding said predefined threshold force; in this way all of the actuators in the assembly are calibrated. For example the method may comprise a step of adjusting the
- 25 current which is supplied to the actuator to operate the actuator to apply a force to the first end 9a of the shaft 9, to find a current level which results in the force applied to the component, when the component impacts the surface, being below a predefined threshold force. The maximum current level which allows this may be identified. Once identified the current
- 30 supplied to each of the actuators in the assembly may be limited to remain below said identified maximum current level.
- [0056] Most preferably each actuator in the assembly is calibrated, in during a calibration step, to determine the relationship between the

different level of current supplied to the actuator and the forces measured by the force sensor (which are representative of the forces experienced by the component) as the component is delivered to the surface for each respective level of current supplied to the actuator; typically a graph of the

5 different current levels versus forces measured by the force sensor are plotted and preferably the slope of the resulting plot is determined; the plot and determined slope is preferably use to determine the maximum current which can be supplied to the actuator in order to stay below a predefined maximum force. Most preferably this calibration is done in a

10 static manner using an external force sensor.

[0057] Various modifications and variations to the described embodiments of the invention will be apparent to those skilled in the art without departing from the scope of the invention as defined in the appended claims. Although the invention has been described in connection

15 with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiment.