STATICALLY DETERMINED GRIPPER CONSTRUCTION

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Abstract The current approach to reducing impact forces during component placement in micro-assembly is to couple the gripper with 5 Degrees Of Freedom (DOF) to the drive unit of the placement device, wherein the mass of the gripper has been reduced maximally. At the end of the placement motion the drive unit will move relatively to the gripper, as linear as possible given the limitations of the construction. During this motion generally stress builds up in the gripper and it becomes over-constrained due to the extra constraints added by the contact between gripper/component and the substrate. Due to this tension the gripper will start vibrating when the gripper rebounces or when the component is released, resulting in significant placement inaccuracies. A solution has been found to prevent the gripper from becoming over-constrained by adding an extra tilting member to the gripper, leading to a reduction of the placement inaccuracies.

Keywords assembly, collision, gripper, impact, micro system, membrane, placement accuracy

1 Introduction

In micro-assembly placement devices are used for assembling components or placing components on a substrate, e.g. a printed circuit board. These placement robots manipulate usually 4 DOF of the component to be placed [1-10]. For the placement devices it is desired to perform a high number of pick and place actions per minute, limit impact forces and achieve high placement accuracies.

The current approach to reduce the impact forces is to couple the gripper to the drive unit of the placement device while leaving 1 DOF unconstrained using a flexible part, wherein the gripper that contacts the component, has a relatively low mass [11-19]. In this setup the drive unit will move relatively to the gripper at the end of the component placement. During this relative motion generally also small lateral displacements occur (see Figure 1).

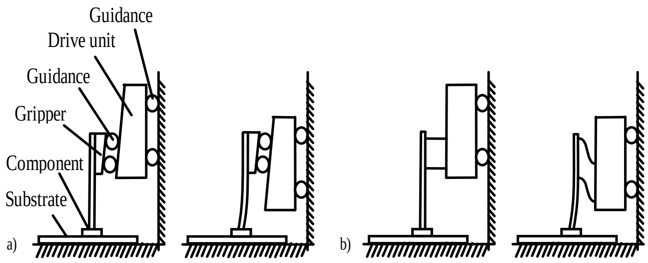

Fig. 1. Movement of drive unit out of line relative to main axis gripper, tension build-up in gripper needle due to the relative lateral displacements: a) roller bearing or sleeve bearing guidance, b) material hinge or leave spring guidance.

These lateral displacements during the component placement can lead to a tension build-up in the gripper. The gripper generally becomes over-constrained due to the extra constraints caused by the high contact forces between substrate, component and gripper and the coefficient of friction between these parts. Due to the tension the gripper can start vibrating when the gripper rebounces or when the component is released, causing significant placement inaccuracies [20-23].

In this article a gripper construction will be presented that does not become over-constrained during the placement collision, leading to a better placement accuracy.

2 Problem analysis

During the collision, the base structure adds constraints to the component when the friction forces at the contact between component and substrate are bigger then the lateral forces. The friction force is proportional to the contact force, which is relatively big (more then 100 times the gravity force) during the collision. The lateral forces depend largely on the angle between the z-axis of the gripper and the axis perpendicular to the top surface of the substrate, which is minimised in most assembly processes. The substrate will therefore generally add three main constrains to the component and gripper: x,y,z (see Figure 2). The rotations R_x and R_y are usually not constrained by the substrate due to the relative small width of the contact area compared to the length of the gripper. The rotation R_z is not likely to be constrained by the substrate due to the small area of the contact point. Therefore during the collision three of the six constrains from the guidance between gripper and drive unit must disappear to keep the gripper statically determined [19, 21, 24].

One of the three constraints that must disappear during the collision is the constraint of the degree of freedom in z-axis. This is because the drive unit will keep moving in the z-direction during and after the collision, and during this motion the gripper is not allowed to make a significant rotation. During the collision the drive unit must also allow freedom (in the order of 10 micrometer) in the x and y direction without changing the x and y position of the component. Therefore the gripper needle must be able to tilt a little around the x and y axis. This can be achieved by

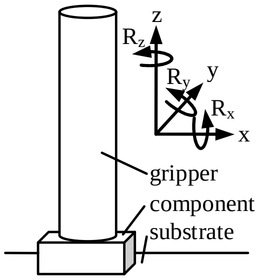

Fig. 2. Axis nomenclature for degrees of freedom gripper

either removing the x and y constrains or the R_x and R_y constrains from the guidance between gripper and drive unit.

3 Concept

Before the component is in contact with the substrate, all six degrees of freedom of the gripper must be constrained by the guidance between gripper and drive unit. When the component is in contact with the substrate, the remaining three constraints must disappear from the guidance. Releasing the constraint in z-direction can be realised relative easily by using a one-directional constrain between gripper and drive unit. This can be done by pushing part of the gripper on a support structure of the drive unit. When the gripper/component comes into contact with the substrate the drive unit moves relative to the gripper causing the contact between gripper and support structure to be broken and the constrain in z-direction will disappear. The constraints R_x and R_y of the guidance can be controlled in a similar way by implementing a tilting member which is pressed in a reference orientation when the gripper is in its reference position.

With degrees of freedom in z, R_x and R_y direction for the guidance between gripper and drive unit when the gripper is pushed out of its reference position, the gripper will not become over-constrained when the gripper/component comes in contact with the substrate. A practical embodiment for such guidance has been found to be a membrane placed transverse to the main motion axis (z-direction) of the gripper. The membrane will constrain the x, y and R_z degrees of freedom of the guidance between gripper and drive unit. A membrane theoretically results in an over-constrained structure in x and y direction but in practice the limited stiffness of the membrane will add an extra internal degree of freedom to the structure, which prevents the membrane of becoming over-constrained when it is around its neutral position.

The z, R_x and R_y degrees of freedom can be constrained when the gripper is in its reference position by implementing a stop piece to the top of the gripper which can be pressed at three points on a support structure of the drive unit (see Figure 3). In the gripper a force is needed to press the gripper to its reference position and orientation. In the prototype this has been achieved by placing a pressurised air chamber

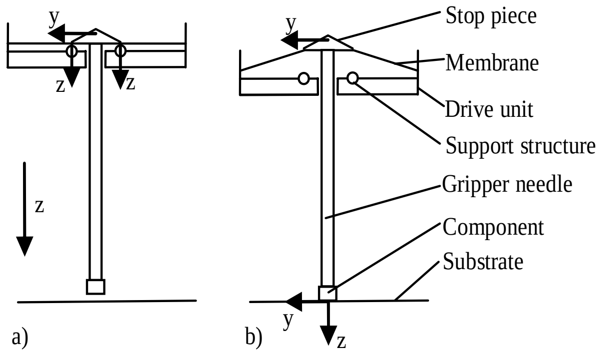

Fig. 3. Schematic gripper concept with membrane as guidance between gripper needle and drive unit. Stop piece controls the gripper in its reference position and orientation when component is not yet in contact with substrate. Arrows indicate constrains in x-z plane. a) gripper approaching substrate, b) component placed on substrate.

on top of the membrane. This force can also be used to prevent the gripper of rebouncing at the end of the placement collision. Components can be gripped for example by implementing a magnetic force on the gripper needle or by adding a vacuum supply to the hollow gripper needle. To allow the component to align with the top surface of the substrate an additional tilting member between gripper needle and component is recommended e.g. a rubber gripper tip.

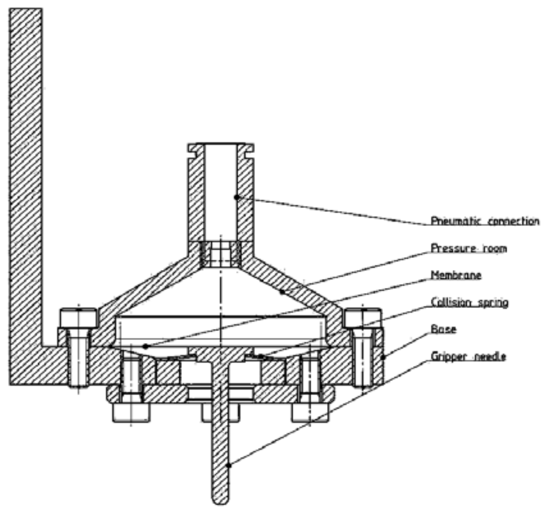

Fig. 4. Prototype of developed gripper for micro assembly: a) drawing gripper prototype, b) realized gripper prototype.

4 Results

A prototype (see Figure 4) of the gripper has been built and tested. The experiments showed that with this concept the drive is allowed to make lateral displacements when the component is already in contact with the substrate without significant tension build-up in the gripper or displacement of the component. An additional advantage of this gripper design is the low weight achieved by using a single membrane as guidance. With an improved design of the gripper prototype a mass of less then 1 g of the components involved in the placement collision was achieved for a gripper equipped with a vacuum supply for gripping the components. A patent is pending for this gripper design.

5 Conclusion

The placement inaccuracies during component placement in micro-assembly can be significantly reduced by preventing the gripper of becoming over-constrained. This has been achieved by implementing a membrane as tilting member in the gripper construction, which adds extra degrees of freedom between gripper and drive unit when the gripper/component contacts the substrate.

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