Influences on the Automated Assembly of Hybrid Microsystems with High Accuracy

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1 Introduction

Nowadays, an ongoing trend of miniaturization of products and components can be observed in nearly all application areas in the world. As for microsystems, a distinction is drawn between monolithic and hybrid microsystems. The latter group requires some kind of assembly process. For the assembly of hybrid microsystems, a high assembly accuracy in the range of a few micrometers is required. In order to reach this accuracy, an assembly system for sensor guided microassembly has been developed at the Collaborative Research Centre 516 "Design and manufacturing of active micro systems". This paper describes the design of a system for automated assembly of hybrid microsystems. The influences on the accuracy will be analyzed on the basis of an example for an automated assembly process.

2 A System for automated assembly of hybrid microsystems

The assembly system for hybrid microsystems is shown in Figure 1. It consists of a parallel robot with an integrated 3D vision sensor. An assembly fixture holding two part trays is arranged inside the workspace of the robot.

2.1 The Assembly robot

The assembly robot for microassembly (micabo-f2) has four degrees of freedom (DOF) used for part handling. One additional DOF is used for focus adjustment of the 3D vision sensor inside its robot head. Two parallel linear drives impart motion in the xy-plane. Each of them is connected to a slide that is coupled to the arms of the structure with rotational bearings. A hollow axis between the arms takes up the robot head, which is designed like a cartridge and forms the tool center point (TCP). Inside the robot head, two drives are installed. One of them moves the gripper and the other one moves the 3D vision sensor in the z-direction. The robot head is turned around the z-axis by a rotational drive.

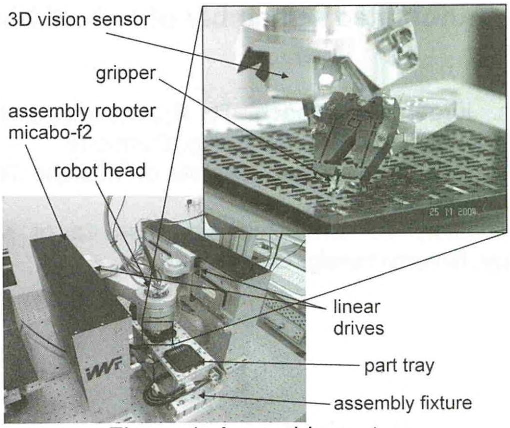

Figure 1: Assembly system

The workspace measures 160 x 400 x 15 mm³ with a good accessibility to the part trays. The control of the parallel linear drives holds the desired position with an encoder resolution of 0.1 µm. In accuracy measurements according to EN ISO 9283 [1], the micabo-f2 achieved a repeatability of 0.6 µm (Table 1). This is a good precondition for a microassembly process.

EN ISO 9283	**P1**	**P2**	**P3**	**P4**	**P5**
Repeatability	0.6 µm	0.5 µm	0.4 µm	0.4 µm	0.6 µm
Variance of Multiple Direction Position Accuracy	0.9 µm	0.6 µm		0.6 µm	

Table 1: Measurement results, robot micabo-f2

2.2 3D vision sensor

The 3D vision sensor system needs only one camera and one image for 3D measurement. Within this system, the principle of stereo photogrammetry is applied. It is based on a 3-dimensional reconstruction of the objects from a pair of images. The field of vision has a dimension of 11 mm in length and 5.5 mm in width with a resolution of approx. 19 µm / pixel. Measurements resulted in standard deviations of σ_x = 0.092 µm and σ_y = 0.114 µm [2].

3 Influences on the automated assembly process

A major task of the assembly system is to validate principles of the assembly of hybrid microsystems. Linear stepping motors according to the reluctance principle, act as demonstrators. The motor parts were mainly manufactured with micro technologies developed at the Collaborative Research Center 516. One sensor guided assembly task is the joining of guides on the surface of the stator element of the motor.

The object sizes reach centimeter range, but have to be assembled with an assembly accuracy of about one micrometer in a relative positioning process. Therefore, a sensor guided assembly process is developed.
Circular positioning marks on the joining partners are used by the 3D vision sensor. Due to the desired relative position of the parts, the vision system calculates a correction vector which is used for position correction.
Influences on the accuracy of automated assembly processes of hybrid microsystems are:

- High repeatability of the assembly robot
- High accuracy of the vision system
- Stable environmental conditions (temperature, lighting)
- Narrow tolerances in geometry of the assembled parts
- Narrow tolerances in clamping
- Displacement during the joining process

As a result of the high repeatability of the developed assembly robot and the 3D vision sensor as well as stable environmental conditions in a clean room environment with direct lighting, a positioning accuracy of less than 0.5 µm has been achieved. There is still a challenge left concerning the displacement during the joining process. Because of this, the reached assembly accuracies vary between (1...30) µm.

4 Conclusion

The assembly system enables a sensor guided microassembly with 4 DOF. An integrated 3D vision sensor offers good accessibility to the assembly scenario. By using circular positioning marks on the objects, the vision sensor reaches a resolution in the submicrometer range. A positioning accuracy of less than 0.5 µm and assembly accuracies between (1...30) µm have been achieved.

5 References

[1] EN ISO 9283: Industrieroboter, Leistungskenngrößen und zugehörige Prüfmethoden. Beuth-Verlag, Berlin, 1999

[2] Tutsch, R.; Petz, M.; Berndt, M.; Hesselbach, J.; Pokar, G.; Heuer, K.: 3D-Sensor for the Control of a Micro Assembly Robot. Optomechatronic Systems IV, Proc. of SPIE, Vol. 5264, S. 267-273, Providence, USA, 2003

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