Assembly of Micro Systems with the High Precision Robot Parvus

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1 Introduction

In recent years, the development of micro systems has been widely discussed in research articles concerning a decrease in size, an increase of complexity and the variety of materials used. In contrast, manufacturing and especially assembly processes of millimetre-sized products with high complexity did not play a significant role. Conventional precision robots that provide adequate accuracies for micro assembly are relatively large and expensive. These machines have to be operated in clean rooms, which results in high costs of maintenance. These days, the assembly technology of electronic production and conventional assembly robots is often no longer suitable for the assembly of hybrid micro systems. The increasing gap between millimetre-sized products and the production machines has lead to a high proportion of manual assembly in the manufacturing process of microproducts. Assembly costs that sometimes account for up to 80 % of the costs of micro systems retard the commercialisation and bulk production of these products. [1] Especially for small and medium-sized businesses, new concepts for flexible and lower-cost micro assembly have to be found.

1.1 Potential for miniaturised robots in micro production systems

To fulfil the aforementioned requirements, the approach of size adapted precision robots can be an appropriate solution for the challenges of micro assembly. The gap between piezo driven, small walking micro robots and conventional robots has to be filled by cost-efficient, miniaturised handling systems. A possible solution is to find out the highest possible degree of miniaturisation of conventional robot technology, using innovative miniaturised machine parts. The feedback of industrial partners and the variety of possible applications showed that the improvement of flexibility by utilising such miniaturised production machines could be important for the overall production process.

Size adapted robotic and desktop factory concepts are based on the following assumptions: Higher density of functionality, operation in a local clean room cell, higher flexibility of place and configuration, high accuracies by smaller machine parts, improved dynamic properties because of reduced mass, lower maintenance costs of small easy manageable systems, lower manufacturing costs of smaller machine parts

2 Description of robot design

Based on the state-of-the-art for precision robots and examples of innovative microproducts, the size of the workspace and the desired performance specifications for the new precision robot, Parvus, were determined. The aim was to find a simple modular structure with a small envelope and easy access to the working area of the robot. The robot should provide four degrees of freedom with three orthogonal translational axes and one additional rotational axis equipped with a vacuum gripper. The iterative analysis of different geometrical parameters and kinematic structures aimed to reach a minimised arm length by keeping a chip-card-sized workspace and high accuracy with a theoretical sensitivity of approximately 1 µm. The decision whether serial or parallel structure should be used was supported by a detailed positioning sensitivity analysis at all points in the workspace of the conceptual designs. [2]

2.1 Innovative drive systems and components

The high degree of miniaturisation of the robot structure is possible because of new enabling technologies, in particular highly dynamic micro-motors with integrated incremental encoders and zero-backlash micro-gears. The Micro Harmonic Drive is the only micro-gear currently available that offers the same positioning accuracy as the large-scale Harmonic Drive gears used in industrial robots.

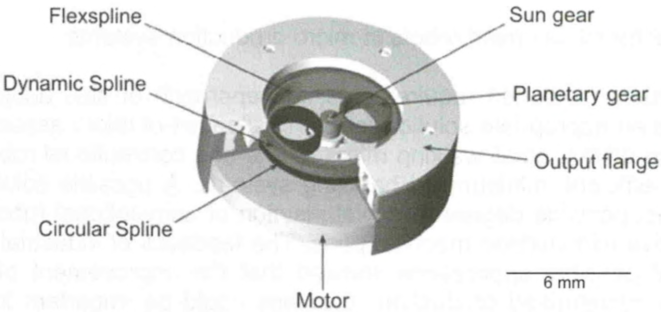

Figure 1: Micro Harmonic Drive gear components [3]

Fig. 1 shows the basic design of this gear, which only needs six components to achieve reduction ratios between 160:1 and 1000:1. These ratios are necessary to transmit adequate torque from currently available micro-motors, which are capable of producing rotational speeds up to 100,000 rpm with torques of only a few µNm. [3]

2.2 Description of final robot design

The final robot design (Fig.2) supports a cubic workspace of 60x45x20 mm^3, a footprint of the whole robot cell of 130x170 mm^2, linear speed over 100 mm/s and a theoretical resolution of about 1 µm. Measurements show that the repeatability of this first prototype is between 5 to 14 µm.

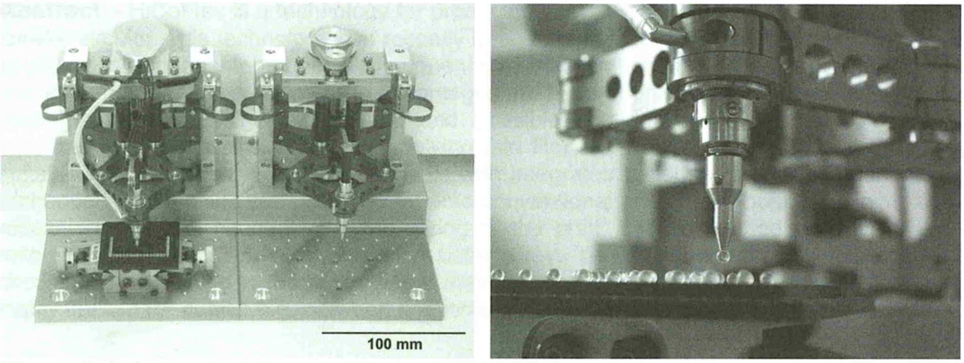

Figure 2: left: two prototypes of Parvus, right: Pick-and-place of glass balls Ø 1.5 mm

3 Conclusion and Outlook

In general, the ranges of application for the Parvus are high precision pick-and-place assembly tasks for any hybrid microproducts e.g. in micro electronic, micro sensors technology, micro optics and medical science. Exemplary assembly processes show the potential of the robot. Further efforts will be to optimise the structure with regard to its repeatability and speed. Regarding a visionary desktop factory, the Parvus will be upgraded with several grippers, different hand axes and part feeders.

4 References

[1] Koelemeijer, S., Jacot J. 1999, 'Cost Efficient Assembly of Microsystems', MST-news, Iss 1, pp 30-32

[2] Burisch, A., Wrege, J., Soetebier, S., Raatz, A., Hesselbach, J., Slatter, R. 2006 'Parvus A Micro-Parallel-SCARA Robot for Desktop Assembly Lines', Proc. of IPAS 2006, 19-21 February 2006, pp. 65-74, Bad Hofgastein, Austria

[3] Micromotion GmbH, An der Fahrt 13, 55124 Mainz, Germany, http://www.micromotion-gmbh.de, December 2007