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6 DOF repeatability measurement setup for measuring position of assembled silicon parts with nanometric resolution.

Johan Kruis[1,2], Pascal Gentsch[1], Pius Theiler[1], François Barrot[1], Florent Cosandier[1], Simon Henein[2]

[1]CSEM (Centre Suisse d'Électronique et Microtechnique), [2]EPFL (École Polytéchnique Fédérale de Lausanne)

johankruis@hotmail.com

Abstract

This article presents a test setup dedicated to the measurement of the 6 degrees of freedom relative positioning assembly repeatability of three micro-manufactured parts equivalent to those composing a mesoscale flexure-based robot. The typical size of the parts is 20 x 20 x 0.5 mm. The parts are positioned with respect to each other by means of a novel alignment method that is under development. The required positioning repeatability is at least 100 nm in translation (x,y,z) and 17 µrad in the rotation (R_x, R_y and R_z). The test setup was realised and the first measurements results of the novel method of alignment are presented.

Assembly, Repeatability, Alignment, 6 DOF position measurements, Micro-manufacturing, Compliant alignment, MEMS

1. Introduction

In the context of repeated micro-assembly it is a challenge to position components with micron and sub-micron resolution and repeatability. A selection of prior work illustrating the domain of micro assembly is given in literature [1-3].

Repeated micro-assembly is interesting for interchangeable robotic systems i.e. a robot of which certain parts can be interchanged with others to create different functionalities or tune the robot to a change in specification. Among the fields of application of these interchangeable robotic systems are scientific instrumentation, astrophysics, medical and watchmaking.

In order to quantify the position repeatability it is necessary to have the appropriate test-setup. This proceeding presents a test-setup providing a solution for measuring the assembled part's linear position and angular position in all 6 degrees of freedom (DOF).

In addition the test-setup was used to conduct a first test on a novel puzzle like alignment method candidate for interchangeable robotic systems. This system was applied to three parts with equivalent size (20 mm x 20 mm x 0.5 mm) to parts of a robot we realised prior [3]. These first results are also presented in this proceeding. The anticipated best case alignment repeatability of this method was 100 nm and 17 µrad.

2. The measurement setup

The setup, illustrated in figure 1 and 2, is based on three Fabry-Perot interferometers (Attocube fps3010) with a 25 picometre resolution and two autocollimators (Möller-Wedel 10/500) with a 5 µrad resolution. In order to parasitic reflections of the autocollimators two black 3D printed plates with holes were designed. The overall measuring resolution of the setup in a conditioned environment is 6 nm and 5 µrad.

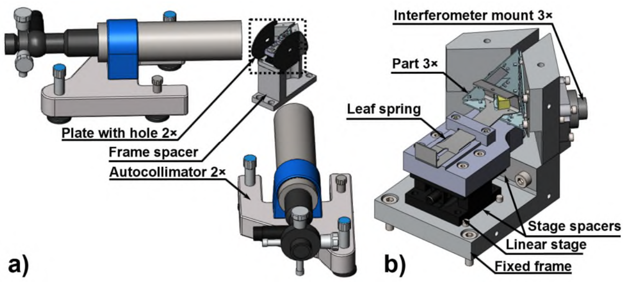

Figure 1. a) Illustrates the entire setup with autocollimators, a frame spacer to be at the right height for the autocollimators, and 2 black plates with holes to block out unwanted reflections; b) The detailed view of the setup with interferometer mount. It contains the 3 silicon parts which align orthogonally to each other. The leaf spring that switches Part C between unaligned and aligned state. A linear stage to position part C. Stage spacers serving to calibrate the setup. And the fixed frame.

In order to guarantee the alignment of the three interferometers with a limited accepted reflection angle (0.075° to 0.295°), each of them is mounted on a membrane containing three leaf springs, shown in figure 2b. This membrane allows for laser angle adjustment of the interferometers non-axial angles.

The setup is placed in a conditioned environment with controlled cleanliness and mounted on an anti-vibration table.

The three parts each have small NdFeB magnets glued into them. These magnets result in that the parts, when brought into pre-alignment, precisely align themselves using their puzzle like features. The parts are illustrated in figure 2.

Part A is always fixed w.r.t. the setup frame. The two other parts, B and C, are constrained w.r.t. to the setup directly prior to alignment, and during alignment are constrained w.r.t. part A.

Part B has a metal slab incorporated and is kept in position prior to alignment by part A and by a fixation bolt.

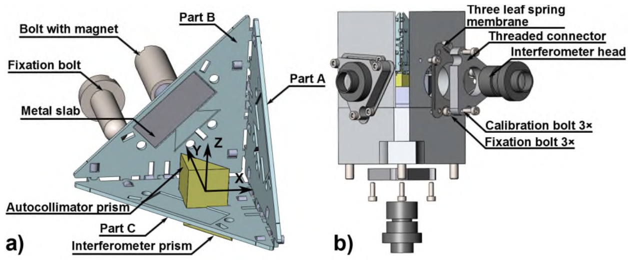

Figure 2. a) The 3 silicon parts containing NdFeB magnets for alignment Part A is the fixed part. Part B is the partially mobile part using a bolt as contact and a bolt with magnet to keep it in position prior to alignment. Part C is the part which has two prisms to perform the measurements with the three interferometers and two autocollimators; b) shows the back side of setup and a more detailed view of the interferometer mounts.

The force to keep it in this position comes from a magnet mounted on a bolt, which attracts the metal slab. The fixation bolt can be changed in position in order to fix the part relative to the setup frame or to allow the parts to align themselves.

Part C is the part containing two prisms (sized 5 mm x 5 mm x 5 mm). These prisms serve as reflective flat references for measurement with the autocollimator and interferometer. Part C is fixed with respect to a linear guide mounted on the setup using a leaf spring (unaligned state). By moving the linear guide and removing the leaf spring; the part is allowed to align with respect to the other two parts (aligned state).

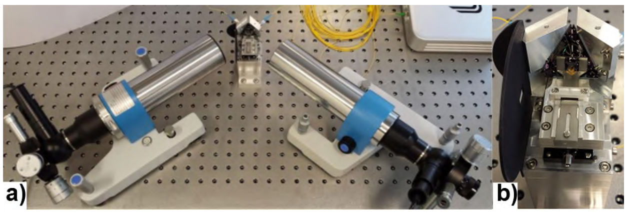

Figure 3. a) The realised measurement setup b) a detailed view of the measurement setup.

3. Setup stability and calibration

The performance of the realised setup in the conditioned environment a set of measurements was done. These measurements took a measurement of one interferometer every 10 seconds for the duration of an hour. This showed that the measurement was stable within 6 nm over an hour.

In order to perform a series of measurements the setup requires a onetime calibration. The stage spacers illustrated in figure 1b serve to provide an adequate gap between part C and the other parts, and limit the stroke of the linear guide so that part C cannot collide with the other pieces during alignment.

The position of the fixation bolt and bolt with magnet illustrated in figure 2a was calibrated for making sure that the pre charge is adequate but does not affect the measurement.

The autocollimators and interferometers are also aligned to the parts in aligned state using their respective mounts.

4. Measurement methodology

To start off measurements, first, part A is aligned w.r.t. a set of stops and fixed on the frame using a set of bolts. Then, part B is put into place with respect to part A and is kept in place w.r.t. the frame by the bolt with a magnet (figure 2b). When both part A and B are mounted, there is an angle of 95°, allowing the parts to align themselves using the novel method. Part C is mounted on the linear stage and the leaf spring is pre-loaded on it. Part C is now moved into position by moving the stage until it is in contact with the spacer plates. After that, the repeatability measurements can start.

For every measurement, the fixation bolt is moved, so that part B moves from a 95° to smaller angle w.r.t. part A. The leaf spring is removed during this process, allowing part C to assemble with part A and B. Finally, the bolt with the magnet is further retracted to allow correct assembly. After which the values of the measurement are noted and then set to zero to measure the next relative position.

5. First results

In total a set of 31 measurements was performed to analyse the repeatability of position of the novel method of alignment. The main results are shown in table 1.

Table 1. The average and standard deviation (σ) of the linear (x, y and z) and angular (R_x, R_y and R_z) position repeatability.

	Average/µm	σ/µm		Average/µrad	σ/µrad
x	0.002	0.17	R_x	0.58	20
y	0.071	0.3	R_y	1.45	23
z	0.29	1.77	R_z	0.84	8.2

Both the X and Y position repeatability are within the submicron range. With the Z position we have obtained a slightly higher repeatability in the order of 2 micron The angular alignment repeatability is within the order of what was expected. Overall the method shows promise for micro assembly.

6. Conclusion and future work

In this paper a novel setup for measuring 6 DOFs of position repeatability of micro-assembly is discussed. The setup was realised and the stability was quantified. It was used to perform a set of 31 measurements on a novel method of alignment for micro assembly applied to silicon parts. Submicron linear position repeatability and angular position repeatability in the order of tens of micro radians were observed.

The future work consists of conducting a longer and more detailed set of tests to qualify the performance of the alignment method. A paper discussing the parts and their alignment method in more detail will follow this work in the near future.

7. Acknowledgements

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References

[1] Basha M A, Dechev N, Safavi-Naeini S and Chaudhuri S 2010 A novel free-space MEMS-based variable optical delay line Proc. Of SPIE vol 7594 pp. 759410-1-759410-8.

[2] Popa D O and Stephanou H E 2010 High-Yield Automated MEMS Assembly *Robotic Microassembly* Gauthier M and Régnier S (New Jersey: John Wiley & Sons) pp 253–278.

[3] Henein S, Barrot F, Jeanneret S., Giriens L, Gumy M, Droz S and Toimil M 2011 Silicon Flexures for the Sugar-Cube Delta Robot 11th Proc of EUSPEN vol 2 pp. 6-9.