DOI: 10.7795/810.20180323B

Clamping of microgears with a compliant string

Stephan Jantzen[1,*], Rudolf Meeß[1], Martin Stein[1], Karin Kniel[1] and Andreas Dietzel[2]

1 Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany
2 TU Braunschweig, Institute of Microtechnology, Alte Salzdahlumer Str. 203, 38124 Braunschweig, Germany

* *Corresponding author: stephan.jantzen@ptb.de*

Abstract

We present a new clamping and handling method for microgears featuring a compliant string. The method simplifies the fixturing and setup process prior to dimensional measurements. The method has been verified experimentally and by FEM simulations. The low-cost prototype shows several advantages over conventional clamping methods like gluing or collet clamping. The clamp is part of a microenvironment that also features a particle shield, cleaning capability and sensors that monitor the direct measurement environment.

1 Introduction

Developments in tactile dimensional micrometrology have improved the ability to perform reliable measurements at the microscale [1, 2, 3, 4]. Clamping of the workpiece during a measurement influences the measurement quality decisively – especially when measuring components with sub-millimeter features, most of which are fragile [5]. Furthermore, proper clamping can simplify handling and cleaning. The applicability of clamps in tactile dimensional micrometrology requires a repeatable, non-deforming, centering and precise clamping of the workpiece. Currently, no specialized clamping system for microgears exists. To address this shortcoming, and to further enhance the measurement of microgears, we have developed a portable and precise yet economical clamping system.

The clamp consists of a compliant string and a tube (see Figure 1). Both components are inexpensive, standard industrial parts. The diameter of the string and the inner diameter of the tube should match the diameter of the through hole of the microgear. The precision and repeatability of the clamp depends mainly on the tolerances of these diameters. A press fit allows precision and repeatability to be increased.

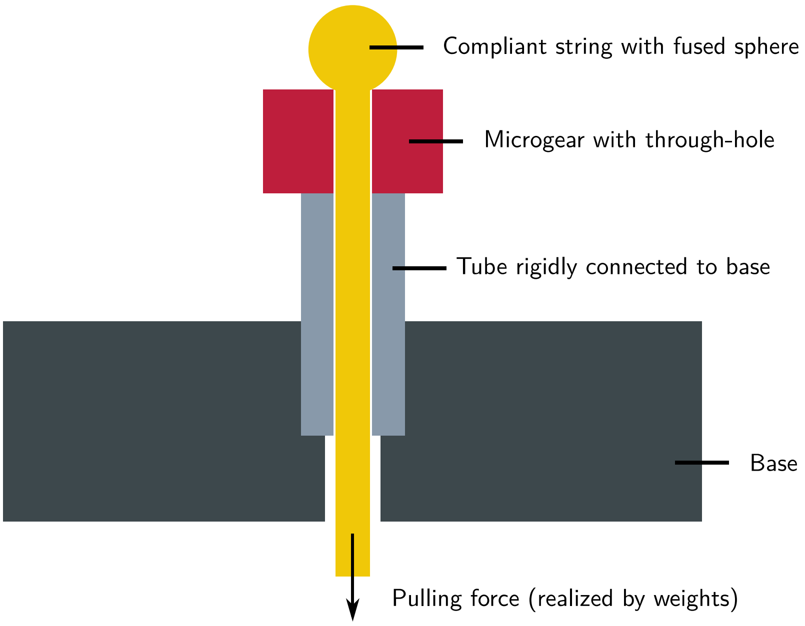

Figure 1: Schematic overview of the new microclamping principle for microgears. The string centers the microgear with respect to the tube. This method allows virtually every workpiece with through-hole diameters down to a few micrometers to be clamped. Threading of a workpiece may facilitate transport and handling

2 Realization and proof of principle

The current setup features a polymer string and an aluminum tube (Figure 2 and Figure 3). Melting one end of the string yields a sphere that exerts the clamping force on the microgear. When the string is pulled, the compliance of the string centers the microgear with respect to the tube. The pulling force may be realized by weights allowing precisely defined clamping forces.

The string also simplifies handling: When the microgear is threaded, transport and cleaning become straightforward, as only the string needs to be handled and not the workpiece itself. The compliance of the string material compensates for possible errors in the roundness of the fused sphere. Several string materials are available (PA, PVDF, PE and nylon). String sizes range from 0.004 mm to 4 mm. To ensure good contact between base tube and microgear, the mating surface should have a high flatness and a concave form to ensure a high repeatability.

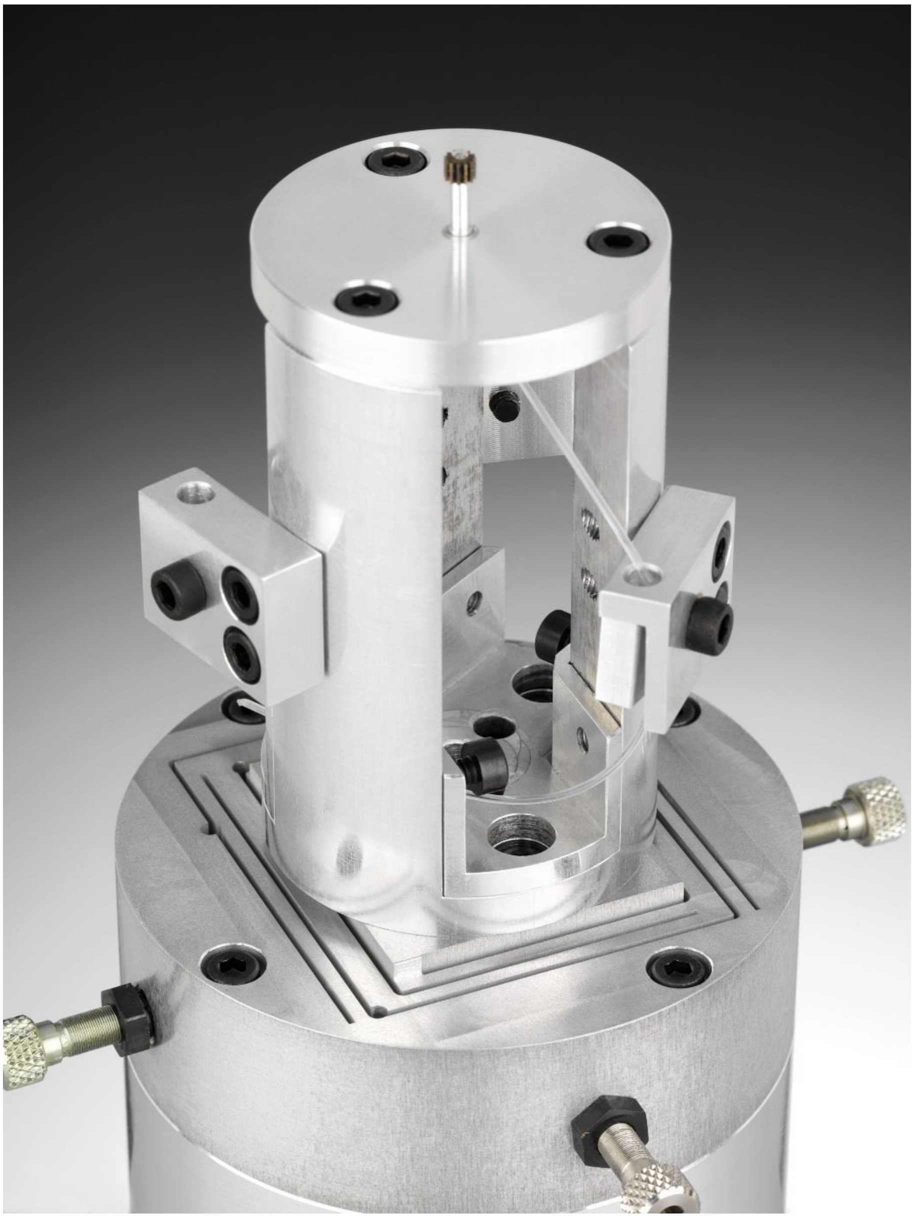

Figure 2: Upper part of the prototype featuring the compliant string clamp. The string material is fluorocarbon and the monofilament has a diameter of 0.9 mm

DOI: 10.7795/810.20180323B

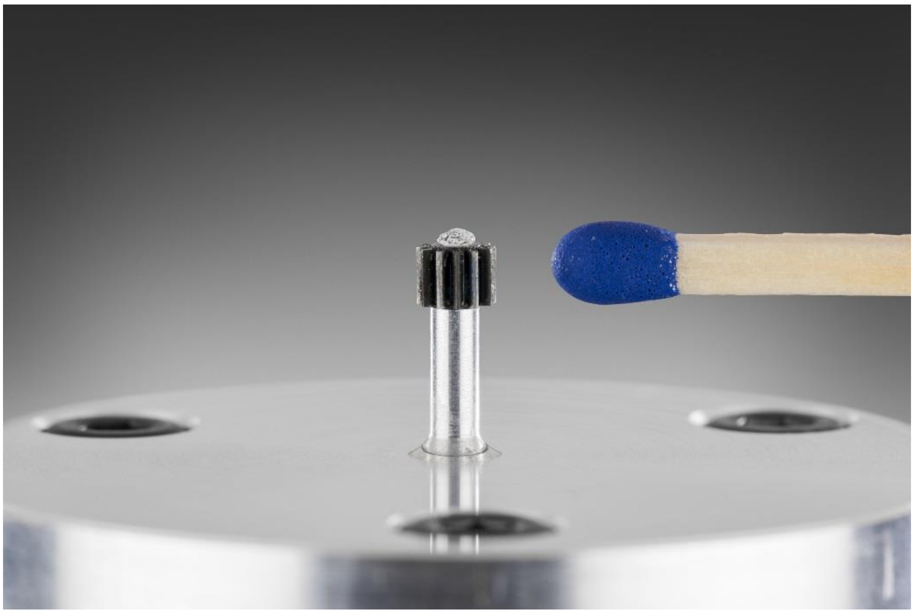

Figure 3: Close-up of the clamped microgear in comparison with a match head. All clamp components (tube and string) are low-cost, mass-produced goods

Using FEM simulations, we computed deformation and tension of a microgear clamped by our string clamp and compared it to a conventional three-yaw chuck clamping. The results show negligible deformation of 21 nm (FEM parameters: high clamping force of 5 N, gear material is steel). Clamping with a three-yaw chuck yielded comparable results.

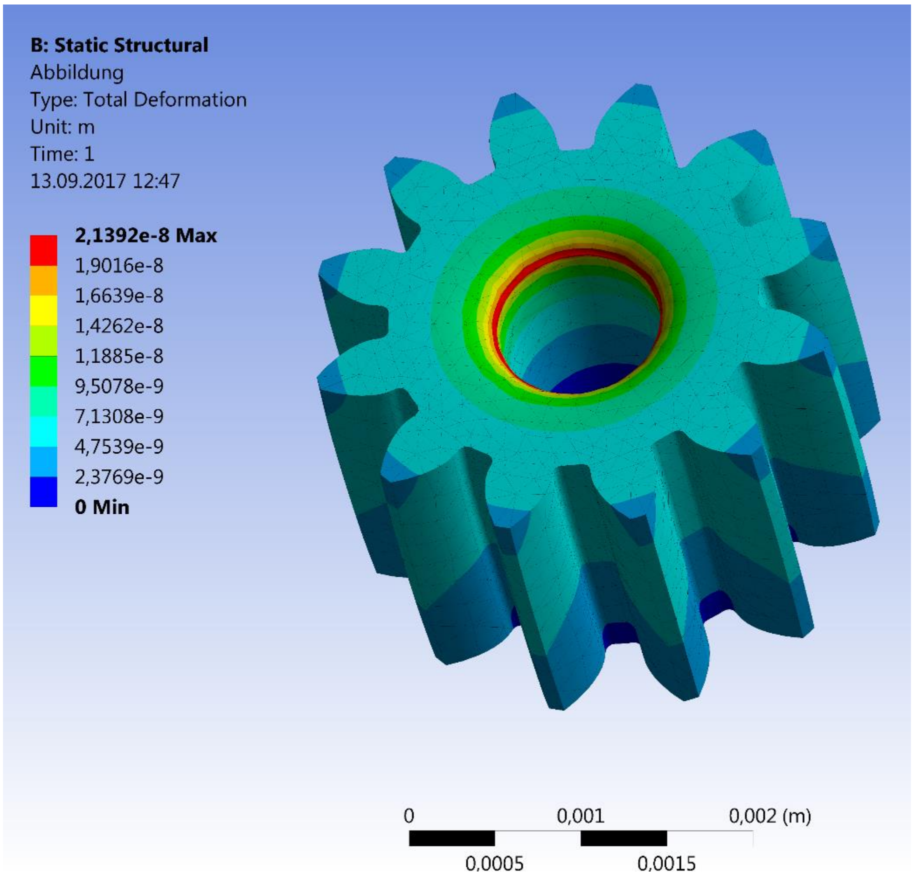

Figure 4: FEM simulation of the string clamp. Deformation and stress invoked by the fixation are comparable to collet clamping and fixation with a three-jaw chuck

DOI: 10.7795/810.20180323B

We demonstrated the applicability and precision of the clamp with a representative microgear (spur gear, module $m = 0.21$ mm, 12 teeth). Further Experiments carried out with an aluminum cylinder as test object compare the eccentricities (Figure 5) featured probing forces of 100 mN and yielded a high repeatability after reclamping (a standard deviation of 7 µm).

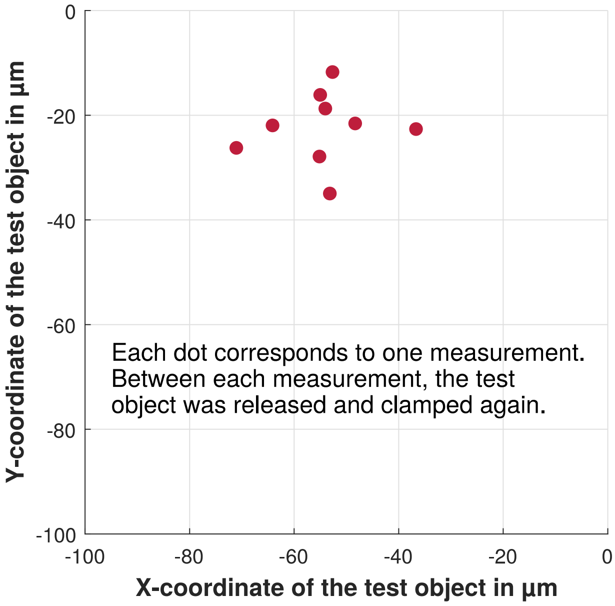

Figure 5: High repeatability after reclamping of the same workpiece, enabling automation of the measurement process since the residual eccentricity is compensated by software of the measuring machine

3 Microclamping principle comparison

To show the advantages of our new clamping principle, we compared the principle with the established clamping principles of gluing, collets and three-yaw chucks (see Figure 6). The clamp requires a matched combination of tube and string for each gear size, which is the main issue of the new string clamp.

	String clamp	Gluing	Collet / Chuck
Measurement interference	None	None	None
Influence on the microgear	Negligible, since string is compliant	Removal of glue residue required	High forces may damage the gear
Robustness and repeatability	String is robust	Positional accuracy is not assured	High
Time needed for setup and release	Seconds	Curing process	Seconds
Ability to center the microgear	Sufficient	Possibility to center by form closure	High
User-friendliness	High + Transport	Use of chemicals, contamination	High
Acquisition and operation costs	Low-cost goods	Gluing station, optical control	High-precision chucks are costly
Scalability of the clamping principle	Relies on available strings and tubes	Precise dispenser and gripper needed	Fabrication limit
Workpiece flexibility	Limited	Flexible	Limited

Figure 6: Comparison of three clamping principles. The proposed clamping principle shows advantages in terms of user-friendliness, costs and unwanted influence on the microgear

4 Conclusion and outlook

The new fixture allows reliable clamping with low-cost components. Microgear handling is easy and fail-safe with the string. The easy-to-use, fully mechanical process exerts a defined and repeatable clamping force via weights. The string treats workpieces gently because of its compliance.

The clamp will be installed on our measuring machine and integrated into our *microenvironment* (see Figure 7). In addition to the clamp, the *microenvironment* will feature an integrated cleaning system and a portable measurement shell to protect the workpiece and microprobe from recontamination and changes in temperature and humidity.

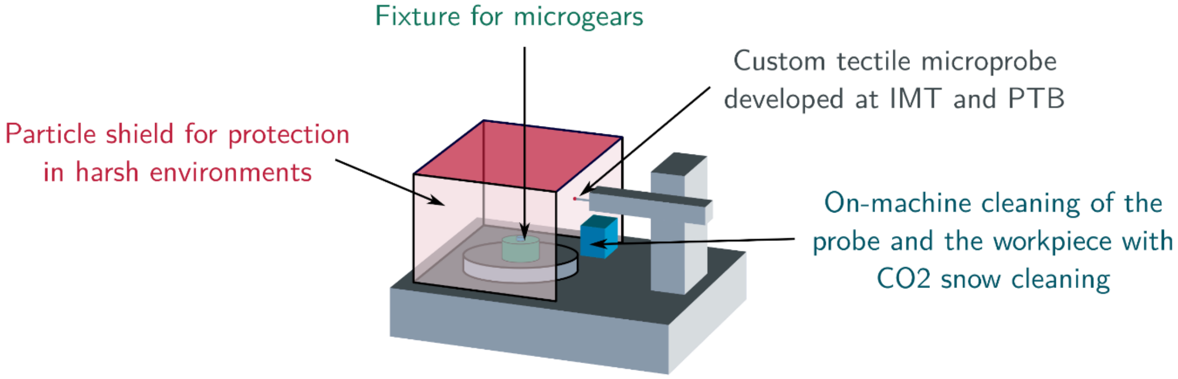

Figure 7: Integration of the compliant string clamp in a microenvironment that features a particle shield, cleaning capability and several sensors that monitor the direct measurement environment (vision system, temperature and humidity sensor, sensor for airborne particles)

Acknowledgement

The authors acknowledge the financial support of the Deutsche Forschungsgemeinschaft, grant KN 1181/1-1, and the Physikalisch-Technische Bundesanstalt, Germany's National Metrology Institute, providing the framework for the research described. We gratefully acknowledge the support of the Braunschweig International Graduate School of Metrology B-IGSM.

References

[1] G. Dai, M. Neugebauer, M. Stein, S. Bütefisch, U. Neuschaefer-Rube, Overview of 3D micro- and nanocoordinate metrology at PTB 6 (9) 257. http://www.mdpi.com/2076-3417/6/9/257

[2] R. Thalmann, F. Meli, A. Küng, State of the art of tactile micro coordinate metrology 6 (5). http://-www.mdpi.com/2076-3417/6/5/150

[3] N. Ferreira, T. Krah, D. C. Jeong, D. Metz, K. Kniel, A. Dietzel, S. Büttgenbach, F. Härtig, Integration of a silicon-based microprobe into a gear measuring instrument for accurate measurement of micro gears 25 (6) 064016. http://stacks.iop.org/0957-0233/25/i=6/a=064016

[4] J. D. Claverley, R. K. Leach, A vibrating micro-scale CMM probe for measuring high aspect ratio structures 16 (8) 1507–1512.

[5] S. Jantzen, M. Stein, K. Kniel, A. Dietzel, Microclamping principles from the perspective of micrometrology – a review, Precision Engineering 50 (2017) 538 – 550. http://www.sciencedirect.com/-science/article/pii/S0141635917300508