Calibration of an Optical 3D Triangulation Sensor for the Evaluation of Precision-Forged Gearwheels

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Introduction

Because of significantly shorter process-chains and expedient material properties, there is increasing interest for the manufacture of gearing using precision-forging techniques. To uncover any geometric errors as quickly and comprehensively as possible, an optical analysis of the entire surface area of the forged gearwheel blanks is performed by the application of a fringe projection system, which works as a 3D triangulation and phase-shift sensor [1-3]. To permit the calculation of gearing deviations, the total geometry of the gearing is recombined from the individual measurement datasets. For this recombination process, a highly accurate determination of the rotation axis, which lies outside of the measuring volume, is essential.

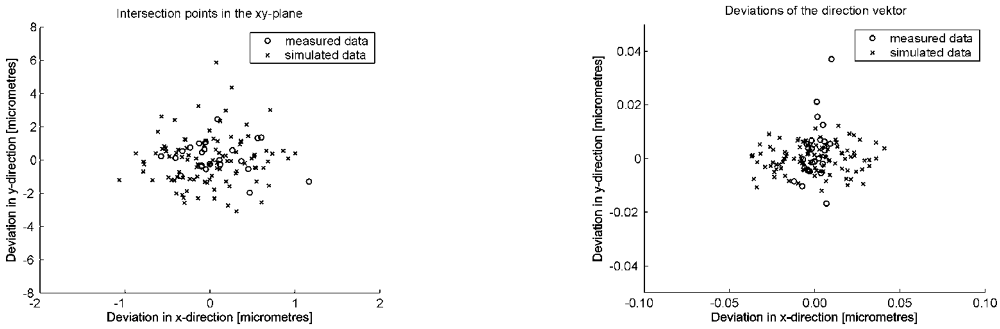
Experimental

The experimental set-up is given in figure 1. The rotation axis is determined by areal measurements on an optical cooperative reference cylinder, whose diameter equals the pitch diameter of the measured gearwheel. These measurements, each providing two sets of measurement data derived from opposing sides of the reference cylinder, are evaluated by the use of cylinders as geometric form elements. At first, the axes of the fitted cylinders are determined, before the symmetry axis of these two axes is calculated. The conclusive rotation axis is calculated as the mean of the symmetry axes derived from the turnover measurements. In terms of an estimation of the measuring uncertainty for the determination of the position and direction of the rotating axis, simulations of the whole evaluation process were carried out.

Fig.1 Experimental set-up

Results and Analysis

The experimental results and the simulated measurements are analysed using statistical methods. Figure 2a shows the deviations in calculating the position of the rotation axis, derived from experimental and simulated data. The deviation is determined by the intersection point through the xy-plane. The standard deviations of both the real (subscript m) and the artificial measuring data (subscript sim) are located in the same order of magnitude (micrometer range) and show an analogue behaviour in x- and y-direction.



a) b)

Fig.2 Comparison of measured and simulated data - a) Deviation of the position vector (intersection point through the xy-plane): $S_{m,x}$ = 0.54µm, $S_{m,y}$ = 0.97µm, $S_{sim,x}$ = 0.44µm, $S_{sim,y}$ = 1.50µm b) Deviation of the direction vector: $S_{m,x}$ = 0.006µm, $S_{m,y}$ = 0.011µm, $S_{sim,x}$ = 0.019µm, $S_{sim,y}$ = 0.005µm

The analysis of the deviations of the x- and y-components of the direction vector shows a similar result (figure 2b). In this case the standard deviation of the x-component of the direction vector derived from the measured data is slightly smaller than that of the simulated data. The standard deviation of the y-component shows the inverse behaviour.

Conclusion

The experimental results prove that the introduced method for the determination of the rotation axis offers the sufficient accuracy and is well suited for the recombination and evaluation of precision forged gearwheel blanks. The stability of the used algorithms was shown through complex simulations of the whole evaluation process.

References

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(3) K. Meeß, Thesis, University of Hanover (2005).

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