Matching of Micro Gears via Dimensional Metrology and Functional Testing

G. Lanza[1], A.Lanza [2], B. Viering[1], C. Becke[2]
[1] *wbk Institute of Production Science,*
Karlsruhe Institute of Technology (KIT), Germany
viering@wbk.uka.de
[2] *Institute of Product Development (IPEK),*
Karlsruhe Institute of Technology (KIT), Germany
becke@ipek.uni-karlsruhe.de

Abstract

Micro gears are characterized by shape deviations caused by micro manufacturing processes, which operate close to physical limits. This paper presents an approach to match micro gears which are afflicted with shape deviations. The approach consists of a geometrical part that couples the dimensional characterization of the tooth flank of a micro gear with a matching simulation and a functional part in which functionally relevant characteristics are derived from functional testing.

1 Challenges for the Functionality of Micro Gears

Multiple industries such as the automotive, medical technology and consumer electronics industries show an increasing demand for micro gears. These micro gears are mostly used in micro gear drives for transmitting torque and rotational speed.

In micro manufacturing the achievable tolerances are limited due to shape deviations, which represent a major challenge for achieving a functioning micro gear drive. The proposed approach to deal with these challenges is to match micro gears afflicted with shape deviations in such a way that the needed function can still be fulfilled. The tooth flanks are especially relevant for the functionality of micro gears because they define the contact area for the transmission of motion. Therefore, the characterizing of the tooth flanks is the most important part when matching micro gears.

2 General Approach for Matching Micro Gears

The transmission of torque and rotational speed of micro gears depends on the contact area and therefore the shape of the tooth flank. Consequently it is important to characterize the whole tooth flank and its deviations. Geometrical characteristics such as profile or helix deviations should be determined via dimensional metrology.

Functional characteristics such as tangential composite deviation or the continuous circumferential backlash should be determined via functional testing.

The measured probing points gained by dimensional metrology can also be used to create a geometrical model of the tooth flank [1]. This geometrical model can be utilized in a simulation to geometrically match two gears. The best fitting gear pairs, as well as the specific tooth combinations, can be identified. The advantage of a geometrical matching of tooth flanks is that even if the tooth flank shapes do not meet the required specifications, the teeth can still fulfill the desired function if matched appropriately. A first statement about the functionality therefore can be made by solely considering the geometrical shape of micro gears.

For more detailed functional aspects, functional testing of a pair of micro gears using a modified tangential composite inspection is conducted [2]. Results can be obtained from these tests. These characteristics can be used to describe the fulfillment of the required function of a specific pair of micro gears. If for example a minimum tangential composite deviation and a certain value of continuous circumferential backlash are desired, it can be stated after geometrical and functional characterization which micro gears with shape deviations should be matched.

One example for a shape deviation could be a flat spot on a tooth flank. This is reflected in the profile and helix deviations from a dimensional measurement. The same shape deviation is also reflected in e.g. increasing tangential composite deviation and increasing continuous circumferential backlash after functional testing. Promising combinations of two micro gears can be identified by using the results from dimensional metrology to create a geometric model and simulate how well the gears match. The results of the simulation can then be verified via functional testing. Through the functional testing of different micro gears with shape deviations, it can be stated, which gears functionally fit best.

2.1 Program and Test Procedure to Match Mirco Gears

The program architecture for the geometrical matching of micro gears was implemented in a MATLAB environment. The structure of the program is shown in figure 1.

The program mainly consists of a start and control function, a function for defining and reading the required variables, a program to fit an ideal involute into a measured point cloud and to calculate the deviations based on [1] as well as a program to match the micro gears.

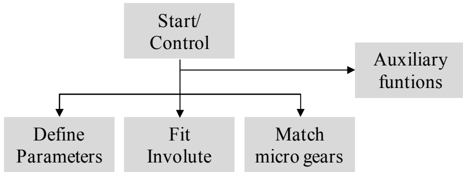

Figure 1: Structure of program to geometrically match micro gears

The program to match the micro gears uses splines. The advantage is that a spline surface can be fitted to the probed points. Therefore the created surface resembles the real shape in a more realistic way than an ideal tooth flank. The spline functions are calculated for discrete areas of one tooth flank and then combined with the corresponding areas of the tooth flank of the matching gear. Finally, the quality of the matched pair of micro gears is described by the deviations of the nominal distance and of the nominal angle of the two gears.

For functional testing, in this approach standard gears with no obvious shape deviations were used. Characteristic shape deviations (e.g. too much or too little (gear K04) material at the tooth base or the tooth tip, too much material along the whole tooth flank (gear K07) or a generally too small tooth) were added to one tooth on each gear. The modified gears were tested in combination with original gears (gear K03) and in combination among themselves at different center distances *a*. By doing so, the effect of a single shape deviation and the effect of an interaction of two shape deviations on the functional properties (here e.g. the continuous circumferential backlash = CCB) can be determined.

3 Results

The results for two shape deviations are exemplarily shown in figure 2-a. Gear K04 shows too little material at the tooth base (resulting CCB in figure 2-b black frame) while K07 has too much material along the whole tooth flank (resulting CCB in figure 2-c black fram). An interaction of these deviations results in a CCB shown in figure 2-d (black frame). It can be seen that the influences of both shape deviations soften each other so that the resulting CCB is smaller in total. This shows that a combination of one gear with too little material at the tooth base and one gear with too much material along the whole tooth flank shows a better CCB than a combination of these gears with gears which have no obvious shape deviations.

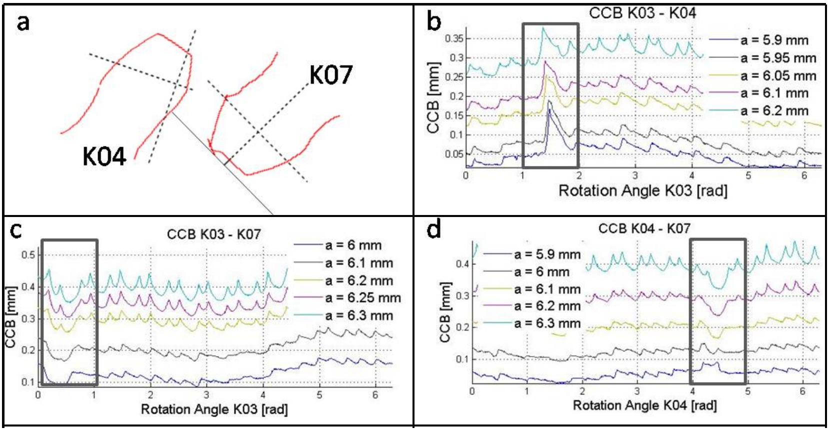

Figure 2: Continuous circumferential backlash (CCB) for different shape deviations

4 Summary and Outlook

This paper showed a functional and a geometrical approach for the matching of micro gears with the focus on influences of the shape of the single teeth which was developed at the Karlsruhe Institute of Technology (KIT). Results showed that an appropriate matching of two micro gears with shape deviations can result in a better functionality than just randomly matched micro gears.

An important aspect that needs to be regarded when describing the shape deviations of micro gears is the measurement uncertainty. Measurement tasks in micrometer dimensions are characterized by a large measurement uncertainty that significantly reduces the useable tolerance field. Therefore, future approaches should also regard the determining of measurement uncertainty for micro gears.

The authors gratefully acknowledge the support of the German Research Foundation (DFG) within the Priority Program SPP 1159.

References:

[1] Lotze, W.: Zahnradmessung mit Koordinatenmessgeräten, self-publisher, Dresden, 2005.

[2] Albers, A. et al.: Validation of micromechanical systems. In: Microsystem Technologies (2008) 14, p. 1481-1485.