Application of an Optical Geometrical Measurement in Quality Assessment of Micro Gears

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Abstract

The profile shape and dimensional accuracy of micro gears affect their performance and functionality in a gear drive to a large extent. However the micro coordinate measuring technology that is usually used to assess the geometric quality faces different challenges. This article introduces a new approach for determining the geometric quality characteristics of micro gears. It works on the principle of chromatic distance measurement and provides a non-contact measurement, thus can be conducted parallel with functional tests. Several experiments are conducted to find the optimum measuring conditions. Results are presented and analyzed. This new approach excels in its efficiency, accuracy as well as the lower cost.

1 Introduction

As an essential part of micromechanical systems, micro gears are increasingly used in many fields to meet different functional requirements. Due to their dimensional specialty (usually with a diameter or external dimension smaller than 20 *mm* and a module smaller than 200 *µm* [1]), compared to macro gears, micro gears are much more susceptible to geometric errors such as profile or shape deviations influencing the dimensional accuracy. An error of several µm could lead to performance loss or even a breakdown of the gear drive. Therefore, it is necessary to assess the quality of micro gears both on functional and dimensional aspects. Figure 1 shows a micro gear and the special functional test rig which were used in this research.

To determine the size, shape and position of micro gears, a common used method is the dimensional metrology, especially in form of a coordinate measuring machine (CMM). Experiences show that a comprehensive measurement with this method usually takes a lot of time, for example 7 hours for measuring a single micro gear that with a diameter of 2.028 *mm* and 12 teeth [2].

In our research, we developed a more efficient measuring method for capturing the working profiles of micro gears which can be conducted during functional testings.

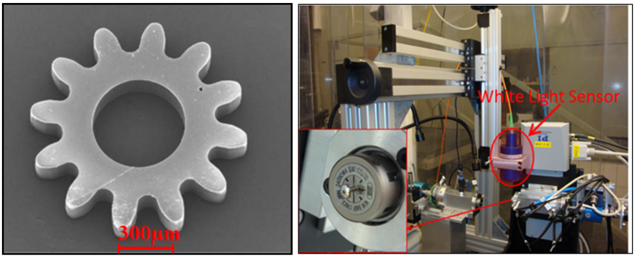

Figure 1: Micro gear with a diameter of 2.028 mm and a module of 0.168 mm (left) and the micro gear test rig used in this research (right)

2 The new measuring method

The new method for micro gear measurement works on the principle of a chromatic distance measurement. A chromatic white light (CWL) sensor is used for measuring the distance between the measuring head and the surface profile of the rotating gear. With this distance (*s* in figure 2) as well as the rotating angle φ measured at the same time, the actual profile of the tested micro gear could be calculated by mathematical algorithms, as shown in schematic diagram in figure 2.

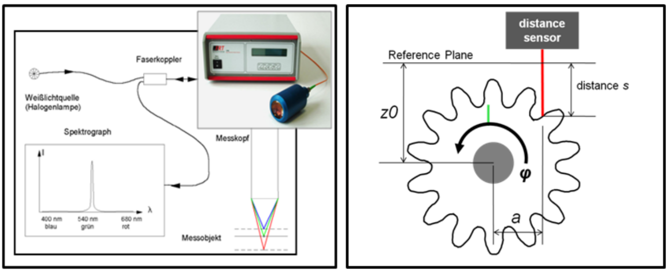

Figure 2: White light sensor (left) and schematic diagram of the method (right) [2]

Because a point on the profile could only be measured when the measuring angle stays within the permitted range (+/-30 grad), so at least three measurements with different sensor offsets (*a*) are needed to obtain the whole working profile. When there is no offset ($a = 0$), the tips and roots of the teeth are captured; when the sensor locates at right / left ($a > 0$ / $a < 0$) sides, the left / right flanks can be captured.

This measuring method benefits by the high accuracy of the optical sensor. The resolution of the sensor reaches up to 10 nm. When it is integrated into test rig for measuring micro gears, the accuracy of the whole system is 3.38 µm [2].

3 Experiment and results

In this research, the authors use micro gears with a diameter of 2.028 *mm*, a module of 0.168 *mm* and 12 teeth to check the effectiveness of this new measuring method. The white light sensor is integrated into the micro gear test rig, so that the dimensional measurements of micro gears could be carried out while their functional tests are running (See the right picture in figure 1). The tested micro gears rotate at a speed of 5 *rad/min*. Each measurement last for about 1 minute.

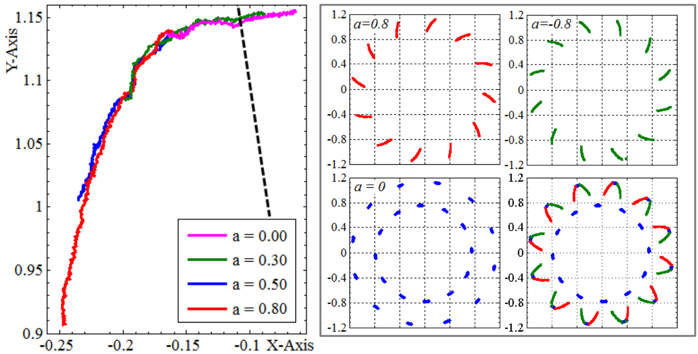

Figure 3: Measured profile parts at different sensor offsets (left) and the fusion contour of tested micro gears from three measured profile parts (right)

Figure 3 illustrates the influence of different sensor offsets on the test results (see the left picture). The curves displayed here are measured profile parts on a half tooth and the black dotted line represents the symmetrical centerline. From this, we see that the measured profile parts at different offsets (i.e. a = 0, 0.3, 0.5 and 0.8) are not the same. When the offset a = 0, the measured profile parts should be the tips and the roots of the tooth. With increasing offset, left flanks can then be measured gradually. The measured flanks reach a maximum when the sensor offset is about 0.8 *mm* (i.e. 0.4-times the size of the pitch diameter). This result matches the calculation very good.

On the basis of this fact, we can now obtain the working profiles of a micro gear only from three measurements: one measurement without sensor offset and two other measurements with an optimum sensor offset at both sides. From those, a fusion contour of the tested micro gear can be generated (see the right picture in figure 3).

Furthermore, we also designed some artificial damages on tooth profiles - for example, part of material was cut down from the tip - to check if this method is still capable of recognizing these damages. As shown in figure 4 (left), a form error is clearly represented in result and matches up with the real damage perfectly.

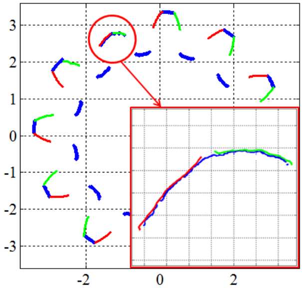

Figure 4: Form damage was measured

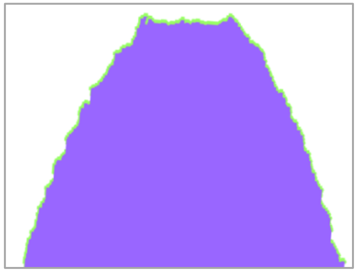

Figure 5: A modelled tooth of micro gear using measured profile

4 Conclusions and Outlook

The discussed optical measuring method is competent for obtaining useful profile details of micro gears and can recognize errors on profiles. In contrast to a coordinate measuring machine, it proves a great superiority of high efficiency. Future research will focus mainly on two aspects: on the one hand determining the geometric quality characteristics of micro gears such as pitch diameter deviation (f_p), profile deviations (F_α, $f_{f\alpha}$, $f_{H\alpha}$) as well as tooth trace deviations using the measured results (e.g. see figure 5); on the other hand developing a quality assurance strategy to use these information for improving the design, production and assembly process.

Acknowledgements

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