Development and Integration of a Method to Support Dynamical Analyses of Micro Gears in Functional Testings

A. Albers, C. Becke, D. Pan
IPEK - Institute of Product Engineering, Karlsruhe Institute of Technology (KIT), Germany
pan@ipek.uni-karlsruhe.de

Abstract

The quality of micro gears is generally assessed by using dimensional metrology. For a more comprehensive investigation of the quality of micro gear drives this research focuses on their dynamical behavior. Therefore a Laser-Doppler-Vibrometer is assessed concerning its suitability for measuring the oscillation of micro gears in a transmission test bench. With the corresponding expertise a new method of failure analysis was both enabled and developed. Creating an opportunity of digital post-processing to analyze the measured data after testing the vibration via the vibrometer system was essential to prove evidence. Using this signal analysis, potential defects of gears can be recognized when investigating the signal sequences.

1 Introduction

Micro gears are a very common part of micromechanical systems, their characteristic dimensions can be miniaturized down to only several micrometers. They are gaining more and more importance in industry and mainly used in medical, semi-conductor and micro-robotics industry to fulfill various functional requirements [1]. Quality assessment of micro gears and micro gear drives can be realized using dimensional metrology like special micro coordinate measuring machines or functional testing methods [2].

Our research focuses on the development of comprehensive quality assurance strategies for micro gears. As the basis of this research, a special test rig for micro gears has been developed, on which a modified tangential composite inspection of two meshing micro gears can be conducted (see figure 1). This functional testing method can get significant results in a short operating time [3]. To detect the dynamical behavior of micro gears, a vibrometer is integrated in the functional test rig. In this research, the suitability for measuring the vibration of micro gears while performing a functional test is investigated. A vibration analyzing method of micro gears is developed. To simulate the actual working situation, various profile damage forms of micro gears are artificially designed. After testing, the signals are processed with digital methods both in time and frequency domains.

2 The measuring and analyzing method

Due to the dimensional particularity of micro gears, the vibration during operation is not easy to detect. When the load is constant, the vibration is in most cases induced by errors on tooth. To recognize the defected teeth, not only the parameters relating to vibration are needed, but also the parameters like rotating angles, time and others. In our research, a Laser-Doppler-Vibrometer is used and integrated into the functional test rig of micro gears, see figure 1.

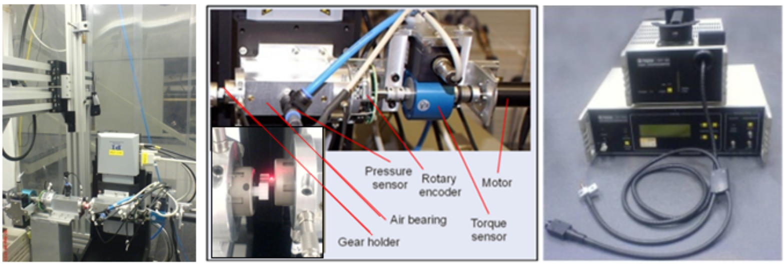

Figure 1: Micro gear test rig (left) with various sensors (middle) and the Laser-Doppler-Vibrometer (right)

After choosing constant signal levels and a correct alignment both of the tested gears and the laser in respect to the tested gears the measuring process can be started. The laser needs to be focused on the hub of one gear not on the tooth profile. The better the reflection characteristics of the gear are the better the test results are. To investigate all left and right gear flanks tests have to be conducted on both rotating directions. Firstly the velocity amplitudes of the measured data are presented in the time domain. The results can be shown e.g. unfiltered, low-pass-filtered, over time, over rotation angle. Then by discretizing the signal the effects of gear tooth defects can be investigated in the frequency domain (Short-Time Fourier Transform (STFT) or Fast Fourier Transform (FFT)), also the power-density spectrum is used to show the intensity of gained frequencies. To combine the insights gained both from time and frequency domain the results are shown in a spectrogram. Thus single frequencies can be assigned with the running time; also a 3-dimensional diagram can be created. Findings can be made by investigating all data, spectrograms and diagrams. Characteristics for gear tooth diagnostics need to be defined and a modified sideband analysis can be used. Thus a qualitative comparison (using a color-coded time-frequency diagram) between the different views (running time, spectrums) gained before with the ideal condition can be conducted. The intensity of the damage can be seen in the power-density spectrum.

3 Experiment and results

In this research, the tested micro gears are made of POM material and with 12 teeth, a diameter of 6 *mm* and a module of 0.5 *mm*. The driven gear has a manual defect on the first tooth (part of the tip was cut off). While testing, both gear wheels run with a speed of 5 *rad/min*.

Gained results show interrelations between the measured data and existing gear tooth defect. Example results in forms of a frequency spectrum, a power density spectrum and spectrograms are shown in figure 2, figure 3 and figure 4.

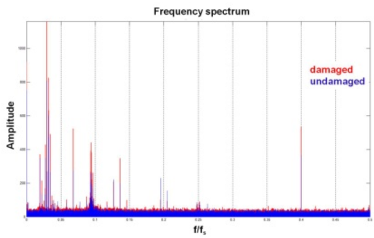

Figure 2: Frequency spectrum for tested micro gears with damage (shown in red color) and without damage (shown in blue)

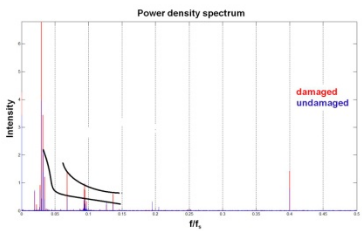

Figure 3: Power density spectrum for tested micro gears with damage (shown in red color) and without damage (shown in blue)

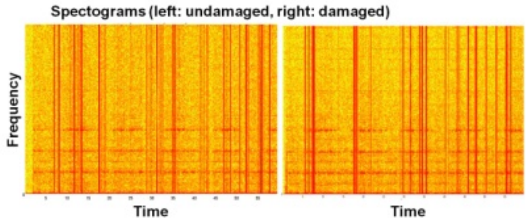

Figure 4: Spectrograms for tested micro gears without damage (left) and with damage (right)

4 Conclusions and Outlook

It was successfully shown that the developed measuring method is capable to detect damages at micro gears. Future research will focus mainly on two aspects: firstly on the optimization of the method to obtain more clear results for different kinds of damages, on the other hand on the definition of characteristics for gear tooth diagnostics to gain statements about the gear quality using the gained data. Finally quality assurance strategies to use this information for improving the design, production as well as the assembly process will be developed.

Acknowledgements

We are grateful for the support provided by the German Research Foundation within the Priority Program SPP1159.

References

[1] VDI 2731, Verein Deutscher Ingenieure e.V., VDI-Richtlinie 2731, „Mikrogetriebe – Grundlagen / Microgears - Basic principles“, Beuth, Berlin, 2009

[2] Albers A., Burkardt N., Becke C., Pan D.: Advantages of Functional Testing in Quality Assurance Strategies for Micro Gears. Proceedings of HARMST 2009, Canada, 2009

[3] Hauser S.; Konzepte zur Validierung geometrischer Charakteristika von Mikroverzahnungen und –getrieben - Concepts for the validation of geometrical features of micro gearings and gear boxes. Dissertation, University Karlsruhe (TH), 2007