The role of mathematical modeling in piezoelectric micro-push motor design

Klaus Kuhnen

Robert Bosch GmbH
Corporate Sector Research and Advance Drives Technology, Power Electronics (CR/ARE3)

Abstract: Piezoelectric micro-push motors are commonly build-up as a fixed vibrating body and a movable bar which is elastically pressed on the fixed vibrating body in a contact point with the normal force F_N. Based on structural integrated piezoelectric ceramics the vibrator is excited to ultrasonic vibrations in such a way that the contact point moves along a high-frequency microscopic elliptical trajectory, see figure 1. Through a dynamically coupled contact and friction force process between the movable bar and the fixed vibrating body the high-frequency microscopic motion in the contact point is transferred through the friction force F_F in a continuous macroscopic motion of the bar with the driving velocity v_T and the driving force F_T.

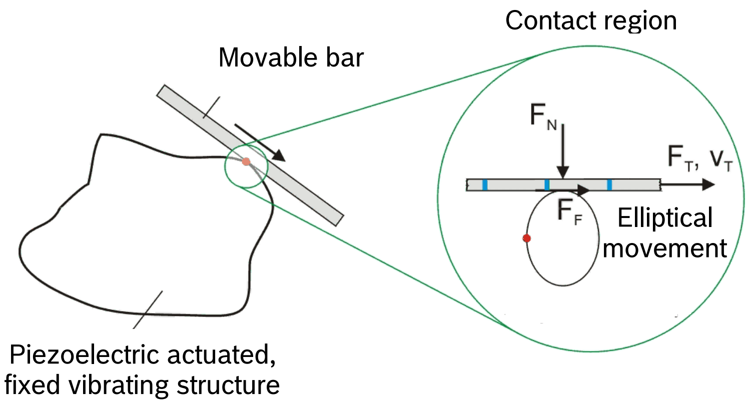

Fig. 1: Working principle of a piezoelectric micro-push motor

A fundamental requirement for the design and optimization of micro-push motors is a deep understanding of the cause-effect relations between the physical domains which are engaged on the driving principle. The physical domains extend over power electronics, structural integrated piezoelectric actuators and sensors, structural dynamics of the fixed vibrating body and the movable bar, tribology of the contact process and load-sided mechanics of the bar. Due to the strong complexity of the driving principle which results both from the complex bidirectional processes in each domain and from the coupling between the processes this understanding is only accessible in form of a mathematical model which makes a realistic simulation of this real-world system possible.

With this challenge in mind the presentation discusses the mathematical modeling of this type of driving principle on different levels and the use of these models in micro-push motor design and optimization. The presentation is closed with a video demonstration of a driving force optimized prototype under no load and heavy loading conditions.