Considerations Regarding the Design of a Power Ultrasonic Transducer with Flat Rectangular Plate

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Abstract

There are several industrial applications, like food dehydration, atomization and textile washing among others, that are enhanced by the use of power ultrasonic transducers with flat rectangular plate radiator. These transducers are composed by three main parts, the piezoelectric Langevin type sandwich, the mechanical amplifier, and the extensive plate radiator. Apart from the general considerations to take into account when designing a power ultrasonic transducer, there are other important aspects to analyze like the application of a prestress in the sandwich and the determination of the dimensions of the rectangular plate radiator to excite the selected mode at the desired frequency. The aim of this work is to provide information about how to simulate the prestress in the piezoelectric stack and its effects using COMSOL Multiphysics® and to assess the vibrational behavior of rectangular plates, comparing theoretical and numerical methods.

The numerical model, including the Structural Mechanics Module, the AC/CD Module and the Multiphysics analysis of COMSOL Multiphysics® allowed us to perform the two specific tasks related to these particular considerations when designing power ultrasonic transducers. The Langevin-type transducer is composed by a four piezoelectric ceramics stack tuned into a thickness vibration mode, a central brass flange and two attached steel masses. When designing ultrasonic transducers for high power applications, it is necessary to apply a static prestress in the ceramic stack in order to avoid large strains that may provoke fractures in the ceramics. The simulation of this prestress can be performed with COMSOL Multiphysics® as a two-step simulation consisting of a stationary study followed by an eigenfrequency or a frequency domain study to determine the behavior of the system. Regarding the modal behavior of the rectangular plate, the Structural Mechanics Module of COMSOL Multiphysics® has proved to be an essential tool. An initial theoretical study can be done using the solution proposed by G.W. Caldersmith, which sets the frequency where the desired vibration mode happens depending on the dimensions and the material of the rectangular plate. This theoretical method can be a good approach for thin plates and for low modes. Nevertheless, for a higher mode or a thick plate, the numerical analysis is recommended. In order to quantify the uncertainty of the theoretical model, the modal behavior of three different rectangular plates has been analyzed by both methods, obtaining a correction factor that allows a more accurate initial approach and that depends on the relation between the thickness of the plate and the distance between nodal lines.