Optimization Of Exponential Horns In Langevin Ultrasonic Transducers Using COMSOL Multiphysics

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Abstract

The efficiency of Langevin ultrasonic transducers for various industrial and medical applications heavily relies on the design and optimization of the exponential horns they use. These horns enhance ultrasonic waves, significantly impacting the performance, strength, and focus of the transducers. However, modifying the form of these horns to achieve optimal performance presents a multifaceted challenge. This study aims to improve the overall performance of exponential horns by using COMSOL Multiphysics software to optimize their geometric parameters.

To begin this challenge, a detailed geometric model of an exponential horn was created in COMSOL Multiphysics. The initial design concept was based on traditional models commonly used in various industries. The optimization process focused on key geometric characteristics, including length, diameter, and tapering profile. The Structural Mechanics Module was used to model the mechanical response of the horns under ultrasonic excitation. Additionally, the Acoustics Module was utilized to examine the propagation of ultrasonic waves through the horn and into the surrounding medium.

The parametric sweep function in COMSOL Multiphysics was employed to systematically vary the geometric parameters and analyze their impact on device performance. The Optimization Module helped determine the most suitable combination of settings to maximize displacement amplitude while minimizing stress concentrations. LiveLink for MATLAB was integrated to automate the parametric studies and efficiently process the simulation data.

Furthermore, the Application Builder was used to create a customized interface for the optimization studies. This tool streamlined the setup and implementation of simulations, enhancing both efficiency and user-friendliness. The COMSOL Compiler allowed for the creation of standalone applications based on the models, enabling broader availability and interaction within the research team.

The research indicated that precise geometric adjustments can significantly improve horn performance. By optimizing the length-to-diameter ratio, the resonance characteristics were enhanced, resulting in more efficient energy transmission from the transducer to the medium.

The improved designs were verified through experiments, constructing prototype horns and testing them with a laser vibrometer. The experimental results closely aligned with the simulation forecasts, validating the optimization methodology. The improved horns demonstrated excellent performance in real-world scenarios, such as achieving more consistent cavitation formation in ultrasonic cleaning and producing sharper images in medical ultrasound.

In conclusion, this study highlights the importance of shape optimization in enhancing the

efficiency of Langevin ultrasonic transducers. Utilizing the comprehensive simulation capabilities of COMSOL Multiphysics, geometric improvements were identified and applied that significantly boost the efficiency and effectiveness of exponential horns. These findings not only advance the development of ultrasonic transducers but also have wide-ranging implications for their use across various industries. Future research will explore combining these optimized designs with advanced materials and manufacturing methods to further enhance the performance of ultrasonic transducers.