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STRUCTURAL OPTIMIZATION OF ULTRASONIC SONOTRODE USING INTEGRATION OF MODEFRONTIER AND ABAQUS

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1. Abstract

An ultrasonic horn is a device that amplifies the input amplitude of ultrasonic vibrations so that the output amplitude is sufficiently large for machining. Design of an ultrasonic horn requires a length that equals a half wave length of the input vibration and in our particular application, a cross section that tapers to a small diameter. To resonate and further amplify the vibration, the natural frequency of the horn should be equal to the ultrasound frequency. The maximum stress within the horn should be below the material yield strength. To meet the design requirements, a set of standard design methods were developed in the past from experimental trials and errors. The standard design methods have seen very little change since their first application and, although they are widely used in many current industrial applications, suffer from the following limitations: first, the traditional experience-based formula design approach of ultrasonic horns, which is case dependent, cannot satisfy a variety of design requirements simultaneously, making the optimal horn design difficult to be obtained. Second, manufacturing a horn to resonate at a specific frequency is a prohibitively expensive and time consuming process, which requires adjusting the natural frequency of the horn by repeatedly removing material from the horn and testing its natural frequency. Third, the standard horn shapes (stepped, conical, exponential and square) are not flexible to meet various design requirements in practice, but have been the ones implemented mostly because of ease of manufacture. This research proposes an integrated platform of design optimization and Finite Element Analysis to obtain a fast, accurate, and automatic optimization approach for the design automation of ultrasonic horns. The optimization platform is developed to achieve the maximum amplitude amplification of the horn while constraining its maximum stress and natural frequency. Sensitivity analysis is conducted to understand the relationship between the horn dimensions and its amplitude magnification. Other possible horn shapes beside the standard ones are also explored by introducing multiple control points for a spline shaped surface as design variables. To evaluate the performance of the integrated platform, the optimized horn is computed for dynamic response and modal analysis using Finite Element Method.