Drill Tools for Earth and Space
Design of a Novel Longitudinal-torsional Ultrasonic Transducer

These measurements are being used to optimize the performance of longitudinal-torsional (L-T) ultrasonic horns at the University of Glasgow. L-T ultrasonic vibration has many applications including surgical devices, industrial welding and ultrasonic motors. Researchers at Glasgow are even developing ultrasonic drill tools for planetary exploration. Due to the low gravity, traditional drilling will be difficult and the next generation Mars landers will require low-reaction devices for drilling into the surface.

Development of Ultrasonic Properties
An ultrasonic horn, also known as a sonotrode, is a metal bar commonly used for augmenting the oscillatory displacement amplitude provided by an ultrasonic transducer. The device is necessary to efficiently transfer the acoustic energy from the ultrasonic transducer into the medium being treated. The ultrasonic horn is commonly a solid metal rod with a round transverse cross-section and a variable-shape longitudinal cross-section. The length of the device must be such that there is mechanical resonance at the desired ultrasonic frequency of operation – one or multiple half wavelengths of ultrasound in the horn material.

Efforts have been made to excite longitudinal-torsional responses in devices using two different techniques; by coupling the longitudinal and torsional modes,
Experimental Modal Analysis

In order to evaluate the behavior of the transducer, the operating modal response is determined by experimental modal analysis (EMA). The effectiveness of the transducer is characterized by its torsionality, which is the ratio of torsional to longitudinal vibration amplitude. The 3-D laser vibrometer was used to measure the response because it allows data to be obtained without affecting the natural frequency, mode shape, or damping, regardless of whether the device is excited in air (unloaded) or under a load representing a real-world application.

Using the 3-D laser vibrometer, responses in three orthogonal directions are acquired at a grid of surface points on the transducer and the modal frequencies and animated mode are extracted using ME'scope software. The results enable us to assess the vibrational characteristics of the operating mode and the frequency spacing between the desired mode and surrounding unwanted modes of vibration. The vibrometry measurements can also be used to validate finite-element (FE) models of the transducer (fig. 3).

Conclusion

The results show that the model can be used reliably to design novel transducer shapes and evaluate the longitudinal-torsional response characteristics to maximize performance of devices.

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