ULTRASONIC ATTENUATION MAPPING IN GRANULAR STEELS WITH HIC AND CREEP-RELATED MICROSTRUCTURAL DEGRADATION

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Ultrasonic attenuation is a microstructure-sensitive parameter in steels, as it is strongly influenced by grain size and structural heterogeneity. Early-stage degradation mechanisms such as hydrogen-induced cracking (HIC) and creep alter the microstructure before macroscopic defects appear, creating a need for quantitative nondestructive evaluation methods capable of detecting subtle internal changes.

The objective of this study is to quantify frequency-dependent ultrasonic attenuation in HIC-prone carbon steel and creep-resistant Grade 91/92 steels and to evaluate its sensitivity to different microstructural regions relevant to early material degradation.

Ultrasonic attenuation was measured using a special arrangement of elongated focus transducer over frequency range 5 to 20MHz. Measurements were carried out in distinct microstructural regions, including the parent metal, heat-affected zone, and weld metal. Experimental results were compared with finite element (FE) simulations conducted at frequencies up to 30 MHz which is exceptional for ultrasonic FE modelling to support physical interpretation and validate observed trends.

The results demonstrate a clear dependence of ultrasonic attenuation on both frequency and microstructural region. Attenuation increases with frequency, consistent with enhanced scattering when the ultrasonic wavelength approaches characteristic grain dimensions. Representative attenuation slopes of $\alpha = 0.095$ dB/mm at 5 MHz and $\alpha = 0.18$ dB/mm at 30 MHz were obtained, showing good qualitative agreement between experimental measurements, FE predictions, and analytical models.

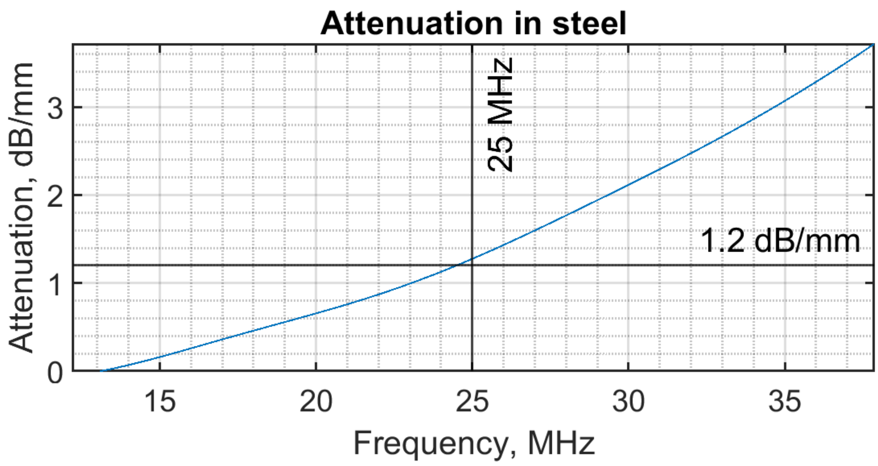

Fig. 1. Example of frequency-dependent ultrasonic attenuation measured in steel, illustrating the determination of attenuation slope α from FEA data.

The study confirms that frequency-dependent ultrasonic attenuation provides a quantitative and microstructure-sensitive indicator for characterizing granular steels. The results support the application of attenuation-based ultrasonic methods for early detection and assessment of degradation processes associated with HIC and creep damage.

Keywords: ultrasonic attenuation; grain scattering; hydrogen-induced cracking; creep damage; non-destructive testing