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Ultrasonic Study of Multiple Scattering and Microstructure Anisotropy in Engine Grade Titanium Alloy

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Ultrasonic testing of jet engine titanium alloys is of high importance for the aircraft manufacturing industry. The quality of these non-destructive testings is severely impacted by the titanium complex microstructure. These alloys have been extensively studied and single scattering models are now well known [1] and implemented in ultrasonic propagation simulators [2]. In addition, titanium billets and forged parts have been known to exhibit a highly anisotropic microstructure [3].

We studied ultrasonic wave scattering in two forged titanium alloys, Ti6-4 billets and Ti17 forged disk, through statistical analysis of the backscattered noise generated by the microstructure. More specifically, we focused on the impact of their anisotropic microstructure, induced by the forging process, on ultrasonic wave backscattering. We used the full matrix capture acquisition with a linear transducer array to quantify the level of multiple scattering in these alloys with respect to the Insonification plane orientation. To that end, we used two techniques. The first one is the multiple scattering filter, recently developed on random rod forest [4] and applied on Inconel alloys [5]. The second is based on a multiple focused beams acquisition [6] to insonify close but yet independent regions of the sample, leading to several independent realizations of the acoustic speckle. A correlation matrix is computed with these realizations and is interpreted through the Van Cittert Zernicke theorem, which allow us to discriminate multiple scattering from simple scattering in a local manner.

Measurements were done at 3.5 MHz and 10 MHz on Ti17 and Ti6-4 alloys which exhibited very different behaviors at both frequencies. Results obtained between both methods are in good agreement.

With our methods, significant level of multiple scattering was consistently measured in Ti17 forged disks. Moreover, Ti6-4 billets showed a regime transition from multiple to simple scattering, which seems linked with the elongation direction of its microstructure.

This result could help us to design inspection procedures that take advantage of the knowledge of the microstructure to optimize the signal to noise ratio, and then discontinuities probability of detection.

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