Defect detection in additively manufactured parts by laser ultrasonic tomography

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Background – As a potential breakthrough technology, the additive manufacturing of metallic parts has raised tremendous interest. It is thus not surprising that methods are highly sought after, that can provide information on the quality of the manufactured parts in a non-destructive and non-contact way. Laser-based ultrasonics is a potential candidate to provide insight into fabricated parts either in-line or as quality check after fabrication [1]. Detection of defects is a) mandatory prerequisite for industrial application and b) optimization of the additive production process. This motivated us to explore this challenge in Ti-6Al-4V parts with intentionally created defects. These are further characterized with µCT as reference method as shown in Fig. 1a).

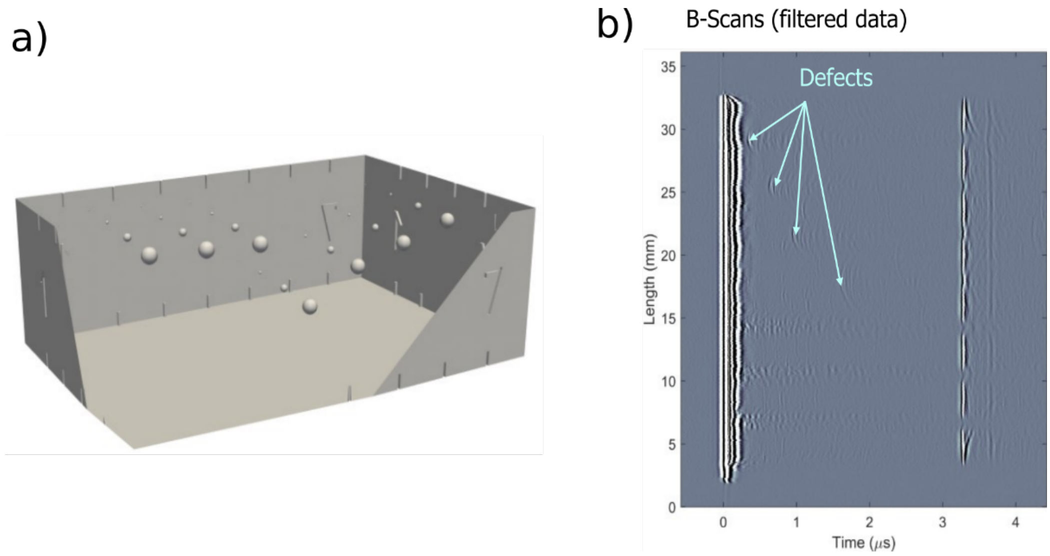

Fig. 1. a) Sketch sample geometry **b)** Exemplary time domain signals along a spatial line scan (B-scan)

Methods – We employ laser- based ultrasound to the optical excitation and subsequent detection of acoustic pulses in the additively manufactured part shown in Fig. 1a). Since the surface is rough a two-wave mixing interferometer is used for the detection due to its robustness against optically scattering surfaces. Several defect sizes (0.1-1mm) in varying depths (0.1-5mm) were intentionally printed in the structure. Characterization with µCT however revealed that only the bigger defects were actually printed as powder filled spheres. A spatial scanning scheme is employed along the sample surface where the time resolved pulse-echos are recorded for each position.

Results – The time-position data (B-scan) shown in Fig. 1b) then reveals the typical signatures of defect backscattering for the deeper defects. Surface near defects exhibit a different spatio-temporal behavior in our data. We find an excellent agreement of μCT and laser-based ultrasonic results for deeper defects but the analysis of surface near signals showed some peculiarities that we will discuss. Furthermore, we find that actual ultrasonic tomography, i.e. applying a spatial 2D scan is very sensitive to unwanted defects that are just barely visible in μCT images under close inspection. Studying the observed features in more detail with supporting simulations are currently under way.

Conclusions – The preliminary findings show a high sensitivity to small defects barely recognizable in μCT images which makes this straightforward approach already a very promising tool for 3D imaging of subsurface defects of additively manufactured parts. All printed defects are recognizable in the ultrasonic scans but a better understanding of the surface near signals is a prerequisite for actual application and further improvements.

References

[1] Honarvar, F., Varvani-Farahani, A. A review of ultrasonic testing applications in additive manufacturing: Defect evaluation, material characterization, and process control. Ultrasonics 108 (2020) 106227. https://doi.org/10.1016/j.ultras.2020.106227.