Statistical Analysis of Ultrasound Signals and Imaging for Evaluating Additive Manufacturing Components

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Background, Motivation and Objective

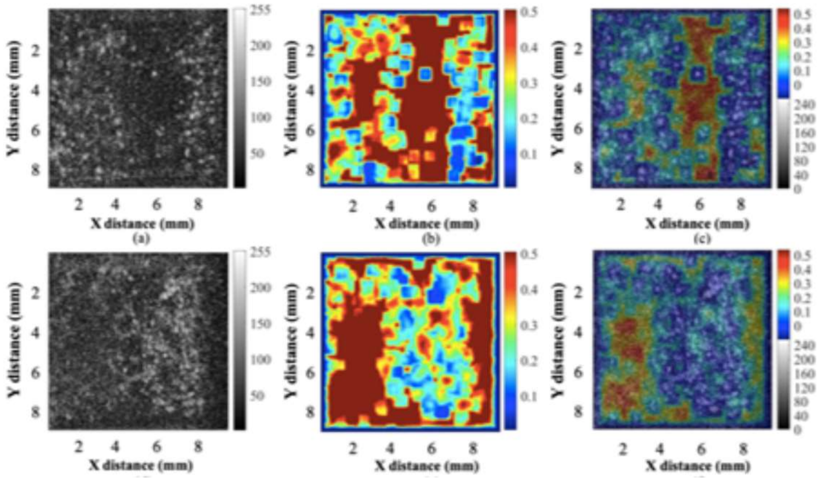
Selective laser melting (SLM) is a commercial available additive manufacturing (AM) approach for producing metallic components. The settings, including laser power, wavelength, beam size and scan velocity, are key factors to affect the quality of SLM products. Thus, it is desirable to establish a feasible technique capable of nondestructive evaluating the AM products for better quality control and optimizing the process settings. Ultrasound is a frequent use modality for nondestructive evaluation (NDE). The defects are commonly detected with the discontinuity and echo amplitude associated with the ultrasound wave propagation in the material. Therefore, the sensitivity and resolution of detection may rely on the ultrasound frequency and material attenuation. To further resolve this issue, in addition to amplitude-modulated integrated backscatter, the Nakagami-based statistical analysis, and imaging, hoping to lessen the attenuation effect, were implemented. The micro x-ray computed tomography (Micro-CT) images were acquired and reconstructed in comparison with ultrasonic results.

Statement of Contribution/Methods

A total of 17 SS316L cube SLM products was prepared for NDE. The samples were produced by various settings associated with the laser powers between 180 and 240 W, the hatching space and the powder thickness of 85 µm and 50 µm. respectively. The volume fractions (*VFs*) of porosity were measured by Archimedes principle, in which *VFs* of tested samples ranged between 0.3% to 3%. A 40 MHz high-frequency ultrasound system was developed, and that is able to acquire 450 A-lines at 20 µm interval with a 500 MHz sampling rate. The parameters and window-modulation parametric images of *IB* and Nakagami statistical parameter were estimated and verified with those slice sections images obtained from Micro-CT and optical microscope.

Results/Discussion

Typical ultrasound B-mode images acquired from the regions of 1.8 and 2.7 mm below the sample surface were able to locally detect the pores of samples. The Nakagami statistical parameter may reflect not only the concentration of pores and flaws, but also the arrangement. Yet, the requirement of a certain window of data for estimating the Nakagami parameter tended to decrease the spatial resolution. The fusion of B-mode and Nakagami parameter images provides performance capable of better visualizing the location and inhomogeneity distribution inside the AM sample. Although Micro-CT images are still with resolution better than those of ultrasound images, the considerations of radiation risk, cost, and time consumption for the mass implementation of NDE tended to limit its application. Moreover, a linear relationship between acoustic velocity (*AV*) and *VFs* of porosity may be established ($AV = -333VF+6503$, $R^2 = 0.625$), that further enabling a quantitative means to assess the AM products.



Ultrasound B-mode, Nakagami parameter, and fusing images (left to right) of AM samples.