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WHITE PAPER

Rapid Quality Assessment in Additive Manufacturing

New Procedure Accelerates Build Quality Assessment

Background

Accelerated growth of the additive manufacturing (AM) industry in recent years is accompanied by a rising need for methods to quickly assess quality at-scale. Current practices for quality inspection include nondestructive test methods and destructive testing of witness coupons, which are artifacts built alongside the actual part. However, these methods can be costly and time-consuming. Recognizing this need, the Additive Manufacturing Center of Excellence (AM CoE) initiated a project led by its partner, Auburn University, to develop rapid testing procedure using as-built samples tested in torsion to quantitatively assess build quality. The presented work developed a rapid testing procedure using as-built samples tested in torsion to quantify small variances for assessing build quality.

Methods

Test specimens included features designed to identify and quantify deviations in build quality. These features include dimensional accuracy, geometric compliance, and mechanical properties. Torsion testing was chosen for mechanical evaluation of these properties. Figure 1 shows the geometry and dimensions of the specimen, as well as an assembly 3-D rendering of the Rapid-Quality Inspection Specimen (RQIS) torsion fixture design.

Process parameters laser power and scan speed were varied in specimen fabrication in order to induce various defect states. This allowed for measurement of the correlation between RQIS results and material quality. The laser-based powder bed fusion (PBF-LB) systems utilized were EOS M290 and Trumpf TruPrint 3000, and the material selected was argon atomized Nickel Alloy UNS N07718 powder. Table 1 presents a summary of the default process parameters. For each machine two batches of 120 specimens were fabricated. 60 specimens were fabricated with hollow (outer diameter = 5 mm) geometry and 60 with solid (outer diameter = 6 mm) geometry.

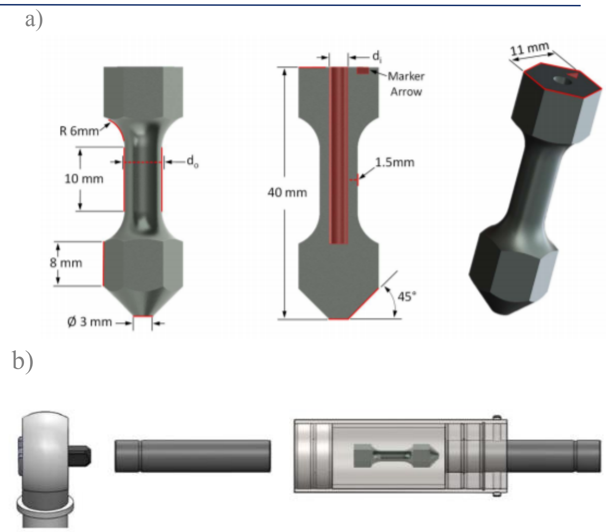

Figure 1: a) RQIS geometry and dimensions b) RQIS torsion fixture design; Assembly 3-D rendering

Parameters	System 1	System 2
Power (W)	285	230
Scan Speed (mm/s)	960	1230
Hatch distance (mm)	0.11	0.1
Layer thickness (mm)	0.04	0.03
Energy Density (J/mm^3)	67.47	62.33
Power to scan speed ratio	0.30	0.19

Table 1: Summary of process parameter

ASTM AM CoE Project:	1901
CoE Partner(s):	Auburn University
Investigators:	Dr. Nima Shamsaei (PI)
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Resulting Work Item:	ASTM WK71395

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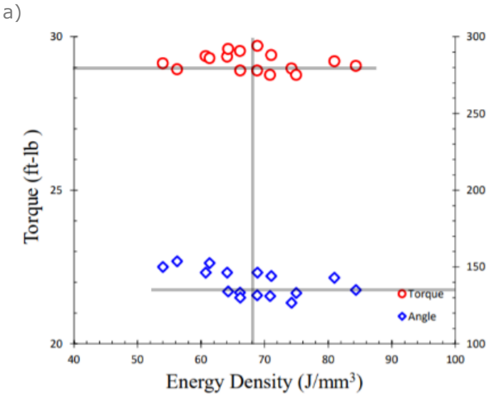
Results

Figure 2 offers a plot of the average values of peak torque and angle of twist for solid specimen compared to calculated energy density. An important relationship to note is opposite trends observed when comparing PBF-LB systems used. For example, an increase in energy density led to increase in torque and angle of twist for Trumpf, while for EOS the values decreased.

a)



b)

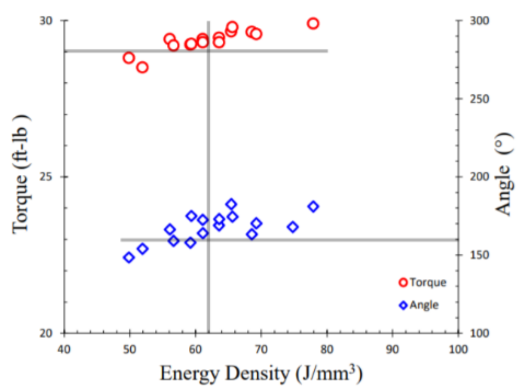


Figure 2: Plots of average values of peak torque and angle of twist versus calculated energy density of (a) solid specimens fabricated with an EOS M290 PBF-LB system and (b) solid specimens fabricated with a Trump TruPrint 3000 PBF-LB system

Figure 3 shows shear stress and angle of twist values collected for all specimens fabricated using default process parameters. As visible in Figure 3, EOS specimens tend to have higher strength and lower ductility whereas Trumpf specimens tend toward the opposite. This may explain the opposite trends that were observed when comparing angle of twist measurements of the second batch of builds.

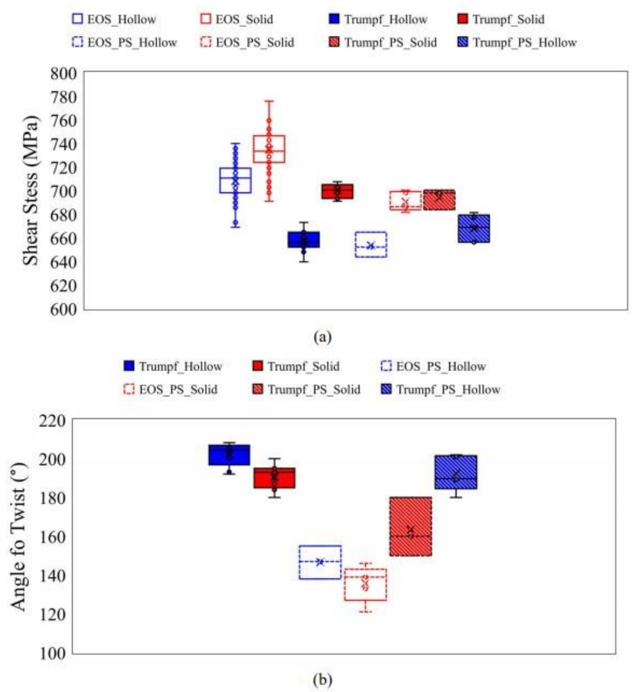


Figure 3: (a) Shear stress, and (b) angle of twist comparison of all specimens fabricated using default process parameters across all fabrications. PS denotes specimens fabricated with default process parameters in the laser power and scan speed variation builds

Conclusions

This research demonstrated the design and implementation of a procedure to detect major build issues shortly after fabrication with AM. Significant results included the highly influential effect of PBF-LB system used on torque and angle of twist values. Regardless of geometry, specimens produced with EOS M290 exhibited opposite trends in angle of twist and torque than Trumpf TruPrint 3000-fabricated specimens. Torsion testing on the newly developed specimens demonstrated that material type has a significant effect on torque values. Angle of twist may be a more effective metric than torque for materials such as the N01778 Nickel Alloy powder used.

In response to the demonstrated need for quality assessment of AM builds, work item WK71395, regarding accelerated quality inspection of build health in PBF-LB, has been initiated and is currently in balloting. Additional specimens have been produced by Jabil Inc. and Sandia National Laboratory in collaboration with this project.

One proposed method for future work would compare differences in sensitivity between torque and angle of twist to determine the utility of each metric in monitoring build health. This work and subsequent projects aim to address current standardization gaps including machine calibration, design for measurement of AM properties and material properties. To validate the extension of this work to additional materials, further work has been led by Jabil Inc. and Sandia National Laboratory in collaboration with this project team. A draft standard covering this test method for accelerated quality inspection of build health in PBF-LB, ASTM WK71395, has been initiated and is currently being balloted in ASTM Committee F42.

About the ASTM International Additive Manufacturing Center of Excellence (AM CoE)
The ASTM International Additive Manufacturing Center of Excellence (AM CoE) is a collaborative partnership bringing together industry, government, and academia. The AM CoE's vision is to facilitate collaboration and coordination between government, academia, and industry to advance AM standardization and expand ASTM and our partners' capabilities. The center bridges standards development with R&D to better enable efficient development of standards, education and training, certification and proficiency testing programs.

About Auburn University
The Samuel Ginn College of Engineering at Auburn University has a long and rich tradition of excellence in engineering education, consistently ranking among the top engineering institutions in the country. Auburn University is a nationally ranked land grant institution recognized for its commitment to world-class scholarship, interdisciplinary research with an elite, top-tier Carnegie R1 classification and an undergraduate education experience second to none. Auburn is home to more than 30,000 students, and its faculty and research partners collaborate to develop and deliver meaningful scholarship, science and technology-based advancements that meet pressing regional, national and global needs.

This work is performed at the National Center for Additive Manufacturing Excellence (NCAME) at Auburn University. NCAME, founded in 2017 through partnership with the National Aeronautics and Space Administration (NASA) and the National Institute of Standards and Technology (NIST), conducts research on improving the performance of parts that are created using AM, shares research results with industry and government collaborators, and responds to workforce development needs in the AM industry. The center is also a founding partner of the ASTM International's Additive Manufacturing Center of Excellence (AM CoE), which directs its efforts to the development of new standards for the AM industry.

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