Impact-Induced Fracture in Additively Manufactured AlSi10Mg Using a Fractal Approach

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Background

- AlSi10Mg is a lightweight and high-performance Al-Si alloy used in the aerospace industry.
- The alloy is suitable for producing parts using the additive manufacturing (AM, known as 3D Printing) technique.
- Engineering parts experience high strain rate (HSR) deformation during functioning in applications.
- AM materials crack propagation characteristics due to HSR impact using a fractal method have not been explored by researchers.

Objective

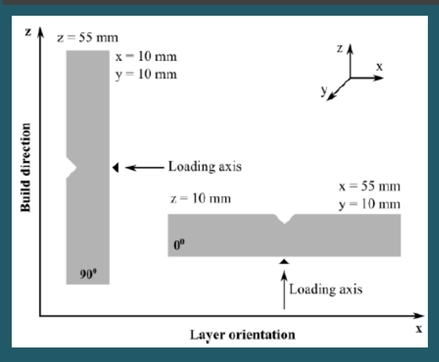
- Understanding the crack propagation characteristics of AM-produced parts at two build orientations.
- Accessing the effect of build orientation on the crack characteristics developed in the impact zone.

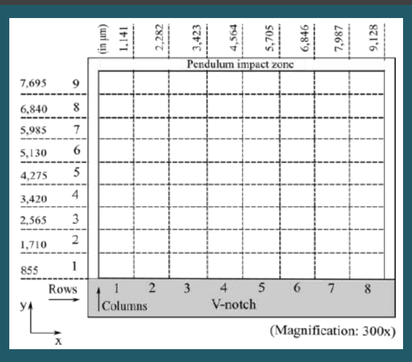
EXPERIMENTAL METHOD

- Charpy V-Notch (CVN) test samples were prepared in accordance with ASTM A370 and AM-SLM process [1].
- The CVN samples were tested with a Tinius Olsen: Model IT 542 Charpy impact tester at room temperature [2].
- The pendulum hammer impact caused crack propagation along the V-notch zone and followed Mode I fracture mechanics.
- A digital microscope was used to investigate the fractured surface.

Sample Preparation Process

- Charpy V-Notch (CVN) test samples were manufactured by selective laser melting process.
- It is one of the AM processes, in which a laser melts powder particles by melting to produce a design installed in the Electro-Optical Systems (EOS) M290 AM machine [2].
- The samples were produced at two build layer orientations: 0° and 90°. For each build orientation, two samples were tested for the fractured surface analysis using the fractal method.
- The global energy density was 37.1 J/mm^3.
- The laser power was 333 W, scan speed was 1430 mm/s. The hatch spacing and layer thickness were 209 mm and 30 mm, respectively. Powder size is 20μm.





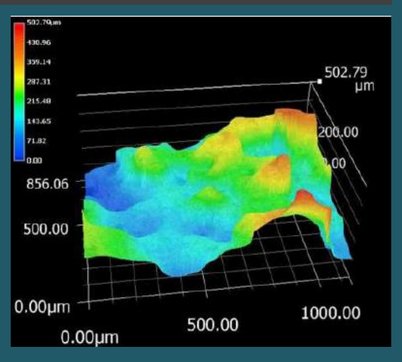


Figure: A schematic diagram of the CVN samples, the box method for fractal analysis, & fractured surface image of one of the boxes [2].

Data Collection & Analysis Method

The fractured surface data were collected and analyzed by the fractal method.

For performing fractal analysis, surface profile data were collected from each of the boxes mentioned above.

The surface roughness data were determined using Underwood and Banerji's model [2].

$$R_s = \left(\frac{4}{\pi}\right)(R_L - 1) + 1$$

Here, R_L is the profile roughness parameter.

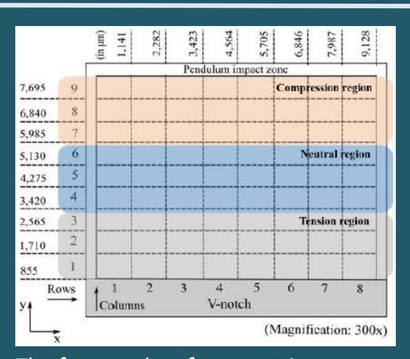
The surface profile data were captured at a magnification of $300x$. The lens calibration factor at $300x$ magnification is 0.633 μm.

Fractal Method

$R_s(d) \propto d^{D_s - 2}$ Here, D_s is fractal dimension [3].

$$D_s = \frac{\ln R_s(d)}{\ln d} + Constant$$

For estimating the fractal dimension from the crack propagation behavior of the fractured surface, we ignored the 'constant' part from this analysis.



The fractured surface contains compression (pendulum impact area), neutral, and tension regions [2].

RESULT & DISCUSSION

Horizontal Symmetrical Crack Propagation

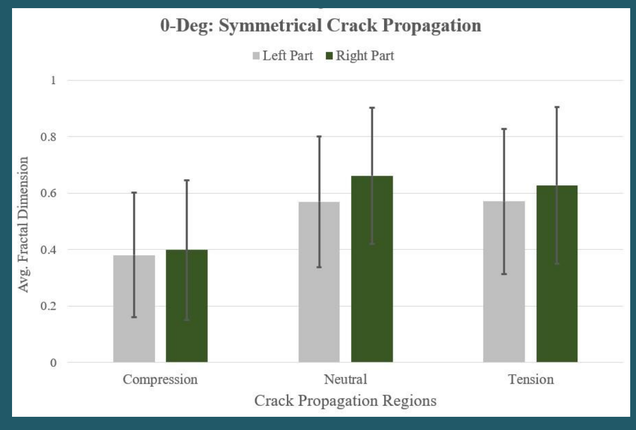
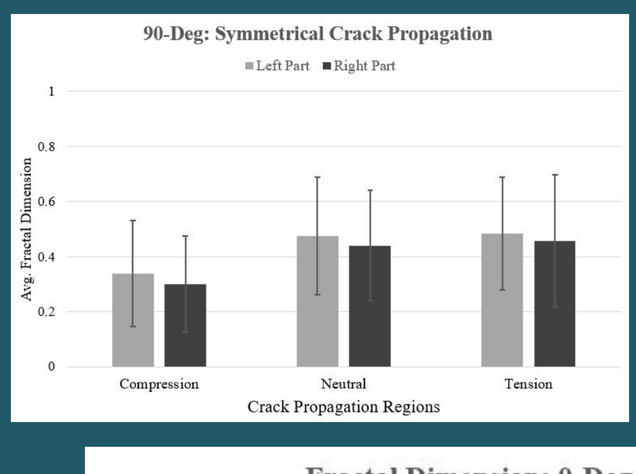


Table: t-Test at each zone (part) of the samples

$n = 24, 24$	P-value	Conf. limit
Compression	$P > 0.05$	Not Significant
Neutral	$P > 0.05$	Not Significant
Tension	$P > 0.05$	Not Significant

(Conf. = Confidence)



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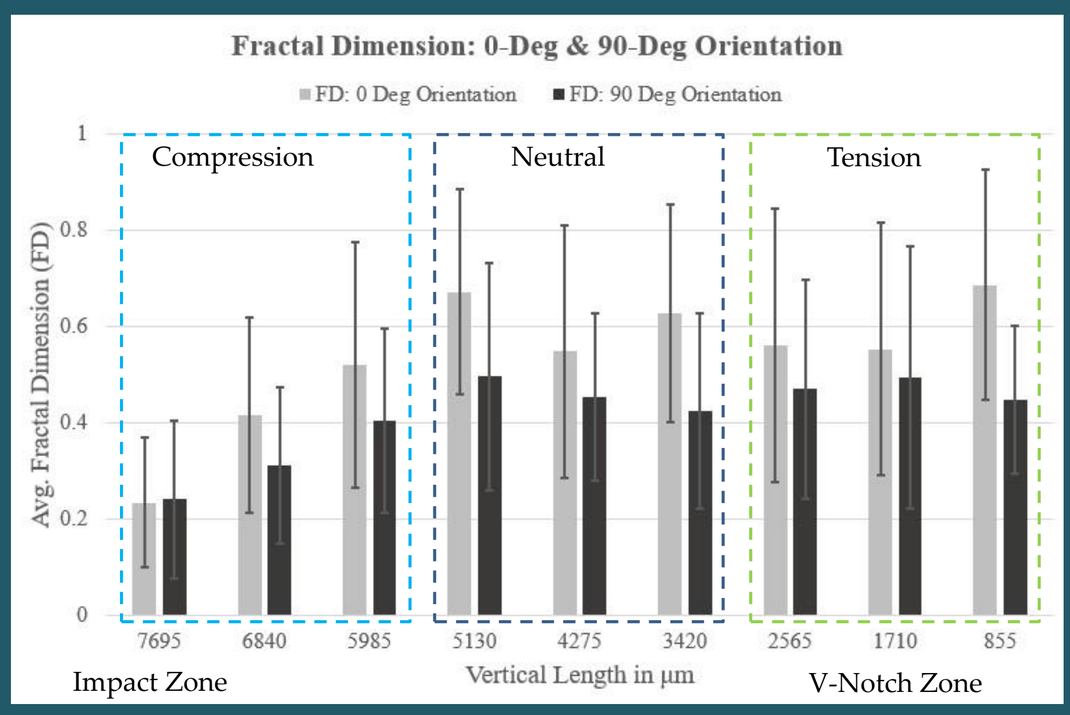

Table: t-Test for 0° samples

$n = 48, 48$	P-value	Conf. limit
Compression & Tension	$P = 0.00011$	Significant
Neutral & Tension	$P > 0.05$	Not Significant
Compression & Neutral	$P = 0.00001$	Significant

(Conf. = Confidence)

Table: t-Test for 90° samples

$n = 48, 48$	P-value	Conf. limit
Compression & Tension	$P = 0.00057$	Significant
Neutral & Tension	$P > 0.05$	Not Significant
Compression & Neutral	$P = 0.00092$	Significant

(Conf. = Confidence)

CONCLUSION

- It was found that the build orientation has an influence on the fractal dimension (FD) for the samples.
- The FD showed similar behavior in the impact region for both build orientations.
- The crack propagation was symmetrical for both build orientation samples and showed compression, neutral, and tension regions.

REFERENCE

[1] ASTM, A. (2014). ASTM A370.
[2] Uddin, M. S. (2020), Graduate Thesis, Montana Technological University.
[3] Zhou, W., Cao, Y., Zhao, H., Li, Z., Feng, P., & Feng, F. (2022). Fractal & fractional, 6(3), 135.

Acknowledgment

Department of Mathematics & Physics, School of Engineering & Physical Sciences, North South University, Army Research Laboratory (ARL) & Montana Technological University: Cooperative Agreement W911NF-15-2-0020.

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