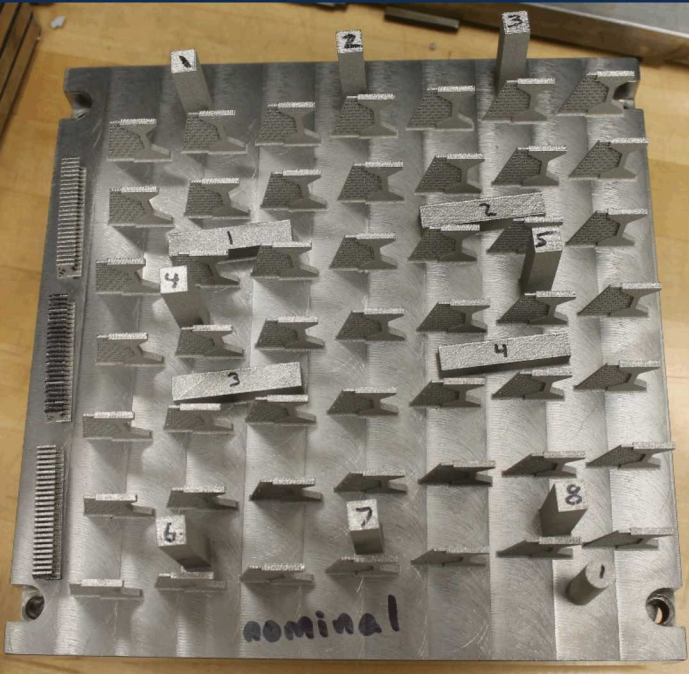


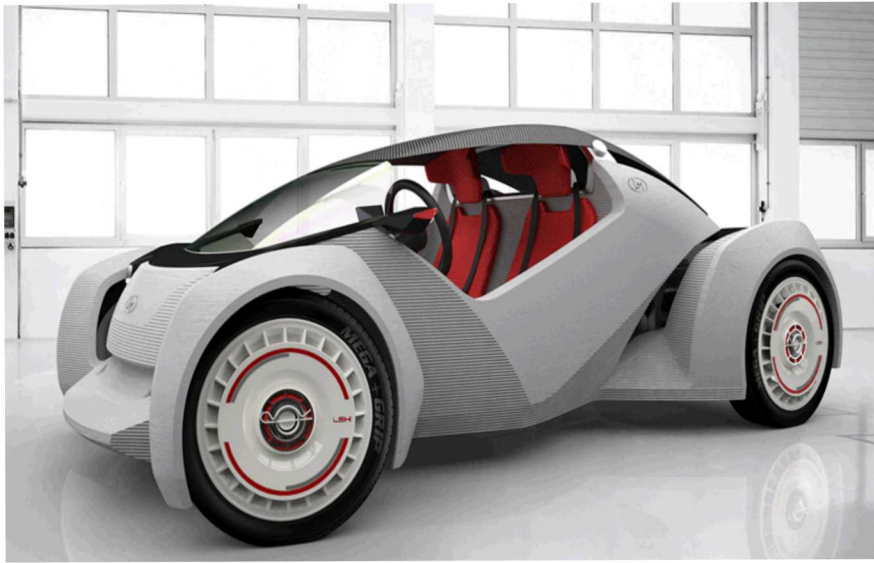
Relating Build Parameters, Density, and Structural Properties in Additively Manufactured 316L Stainless Steel

Isaac Valdez, Dr. Carroll, Dr. Boyce
Todd Huber, Aron Robbins

In collaboration with the Material Mechanics & Tribology Department and
Sigma Labs Inc.



Additive Manufacturing is 3D Printing of Metals



<https://sites.psu.edu/rclperdue/2015/02/11/the-amazing-technology-behind-3d-printers/>



<http://www.totalkustom.com/3d-castle-completed.html>



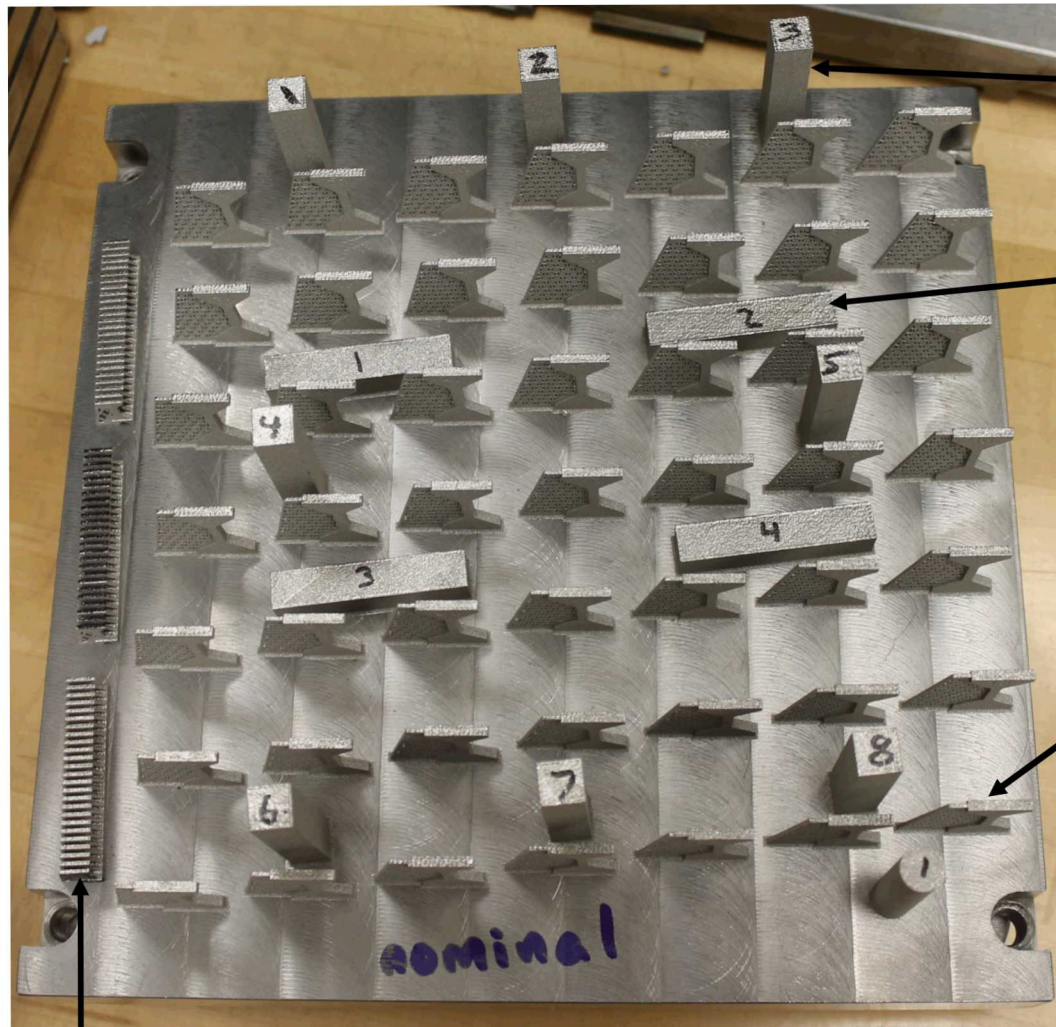
<https://www.ge.com/reports/mind-meld-ge-3d-printing-visionary-joined-forces/>



Powder bed additive manufacturing melts metal powder with a laser



We printed 3 build plates of test coupons



Vertical Charpy Specimens (8)

Horizontal Charpy Specimens (4)

B-size tensile bars (42)

A-size tensile bars (75)

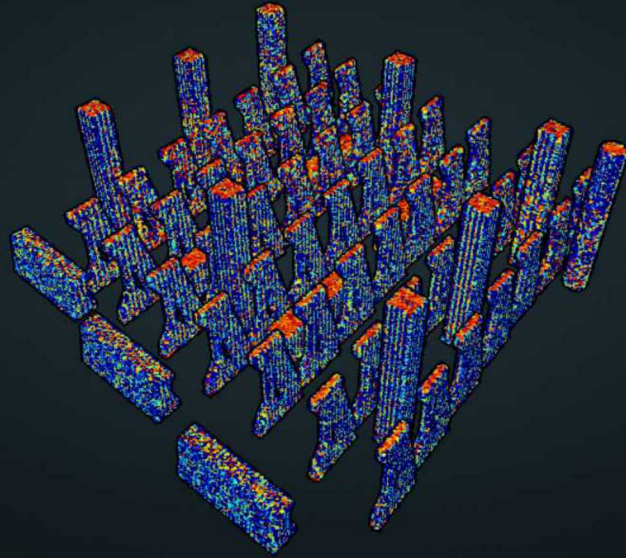
Build Plate includes:

- Charpy Bars
 - Horizontal
 - Vertical
- Tensile Bars
 - A-Size
 - B-Size

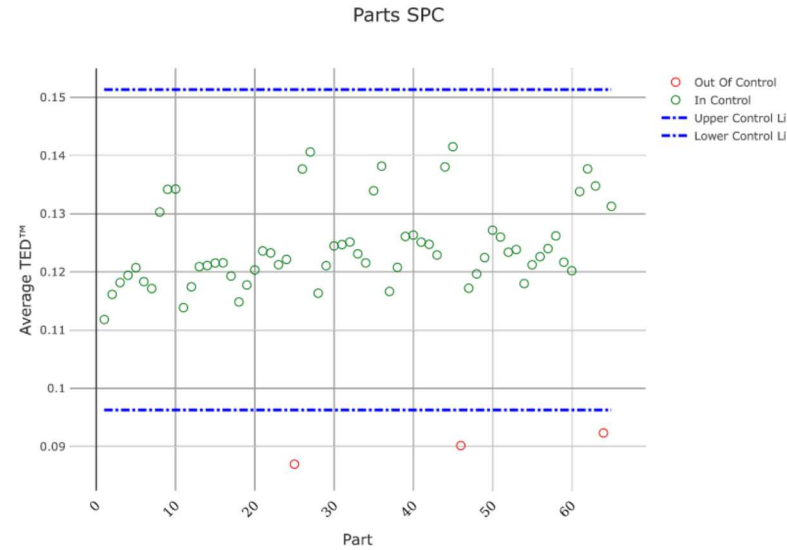


Research Question: TED (Thermal Energy Density) is measured on each layer during printing. Can TED values predict the material structural behavior?

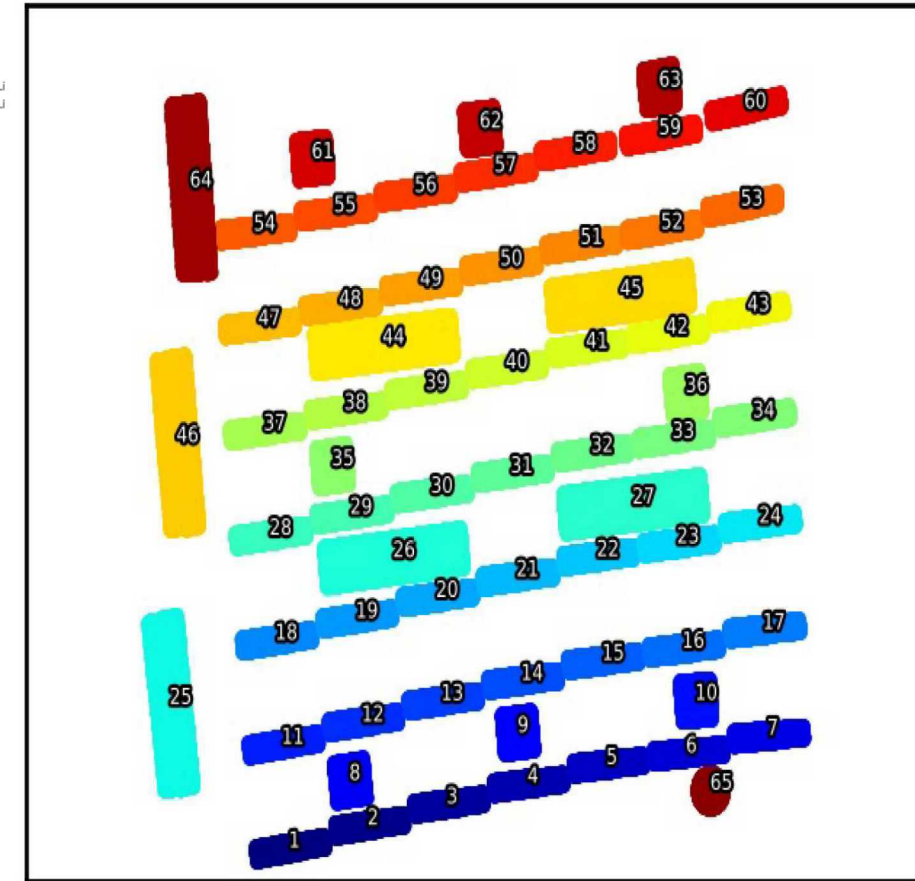
Point cloud of TED values



Ted values vs part #



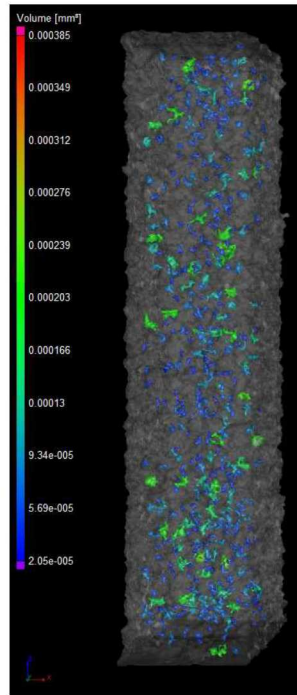
Specimen Layout Map



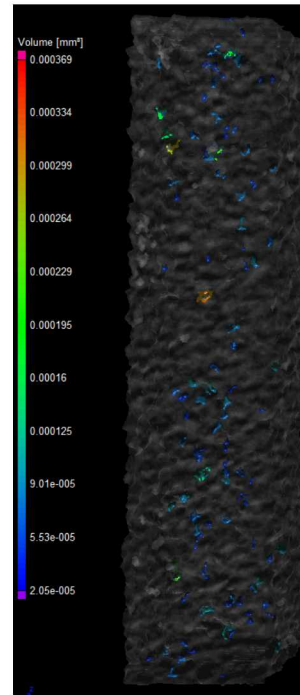
- Level of builds:
 - Low Power
 - Nominal Power
 - High Power

Porosity Measurements from build plates

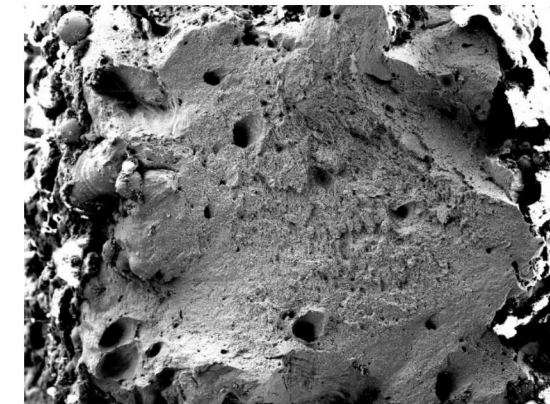
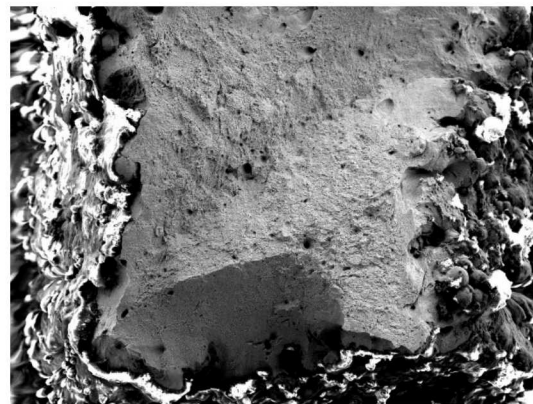
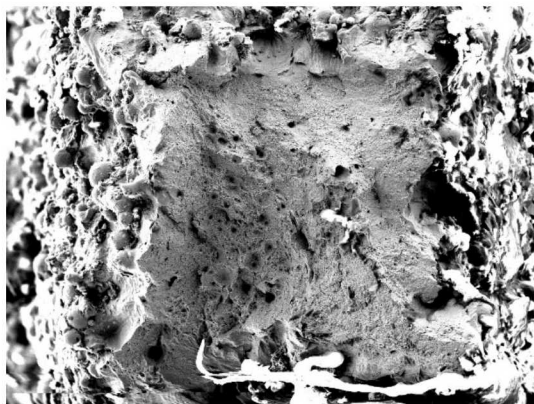
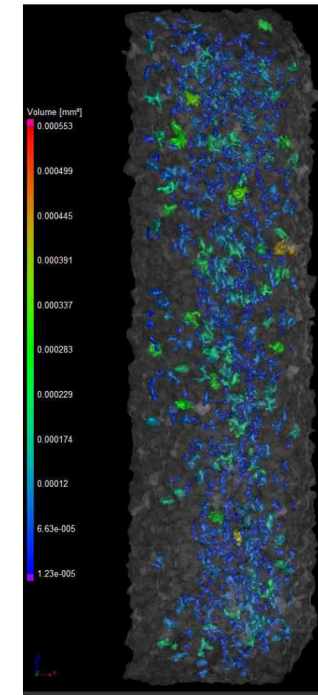
Low



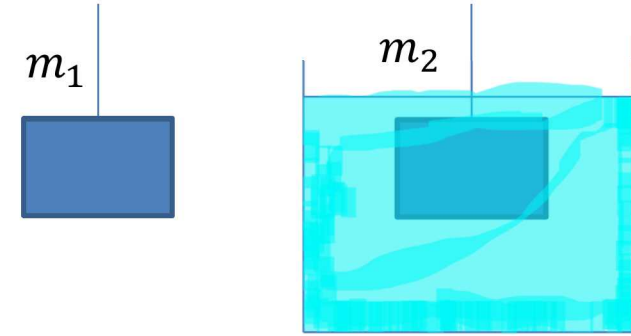
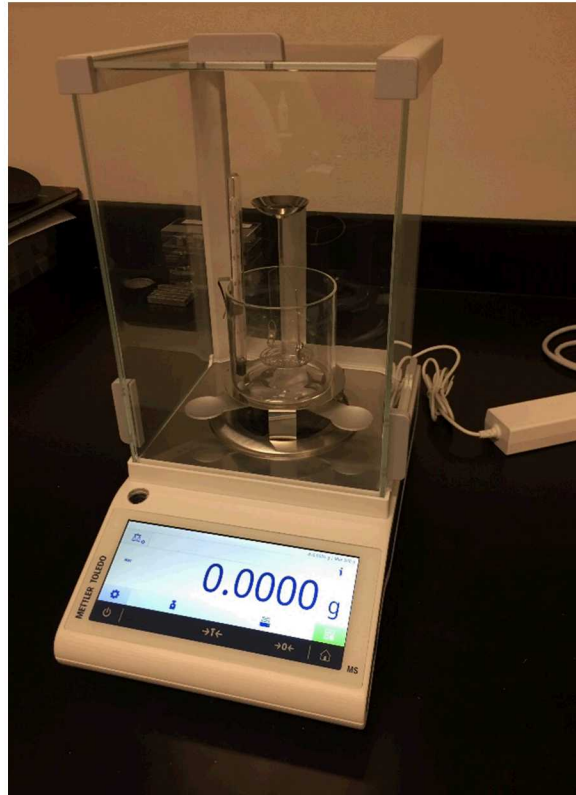
Nominal



High



Measuring the density of Charpy bars using the Archimedes method.

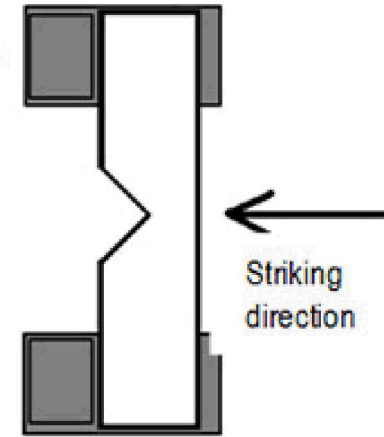


$$\rho_{\text{solid}} = \rho_{\text{water}} \left(\frac{m_1}{m_1 - m_2} \right)$$

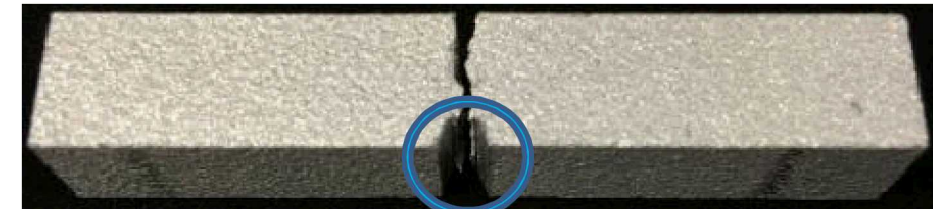
Use Charpy testing to determine the amount of energy that is absorbed in each sample.



Charpy impact test



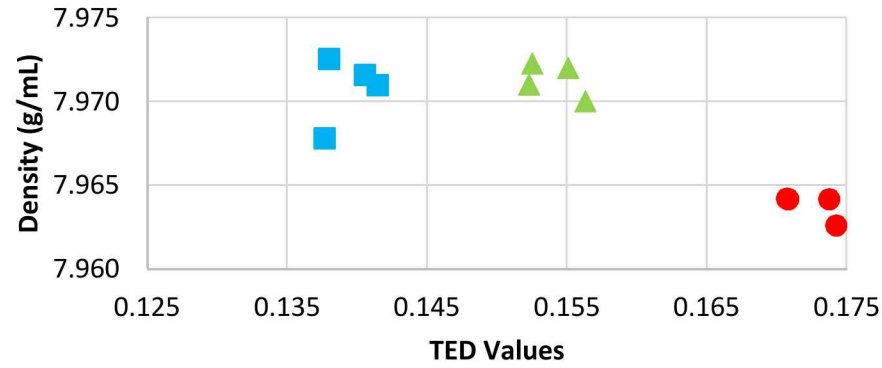
<https://www.mcanac.co.jp/en/service/detail/6a002.html?c1n=by+Chemical+Structure&c1s=structure&c2n=Polymers&c2s=01>



Notch

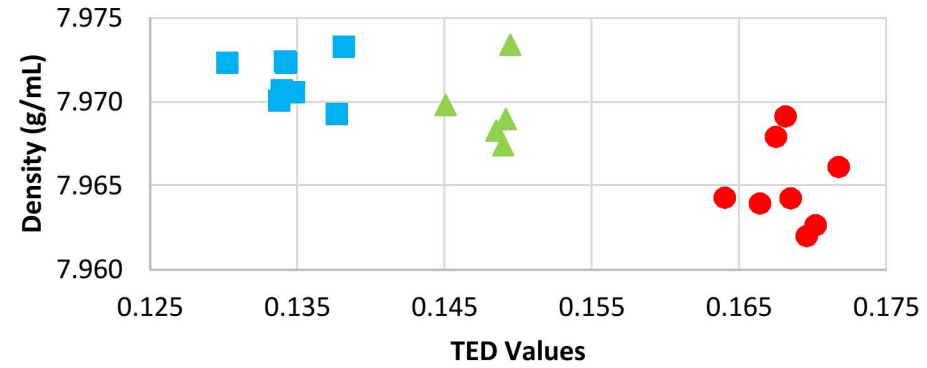
Density vs TED

Density vs TED Value Horizontal



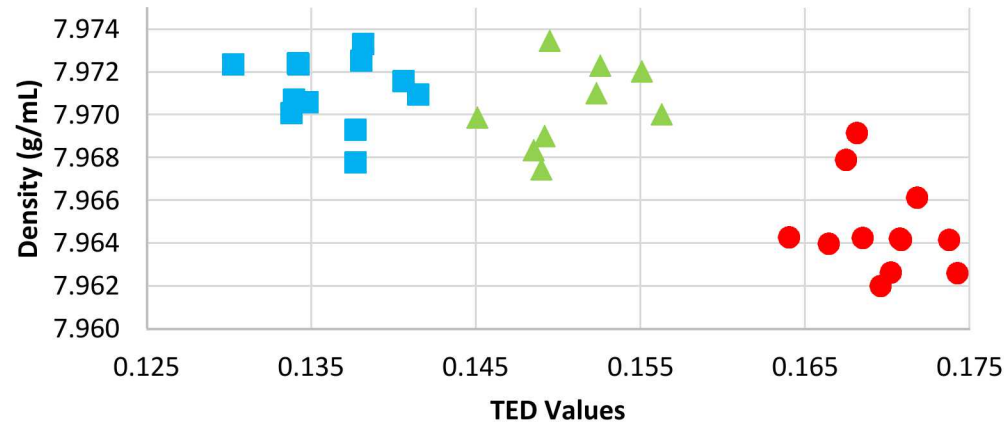
■ Low ▲ Nom ● High

Density vs TED Values Vertical



■ Low ▲ Nom ● High

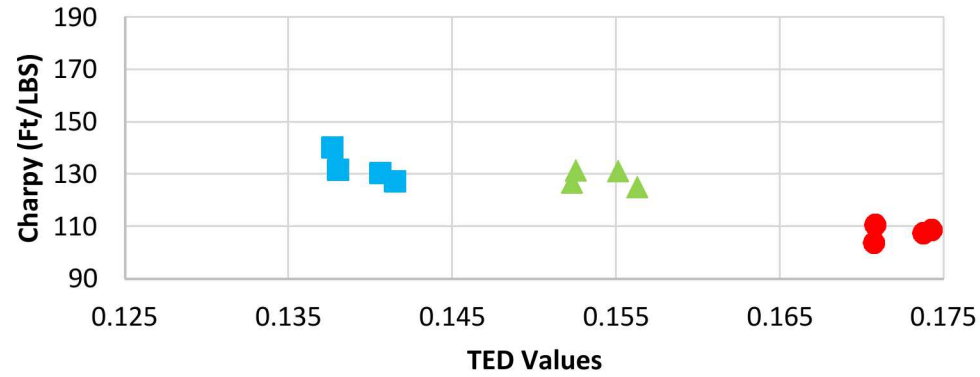
Density vs TED Value All



■ Low ▲ Nom ● High

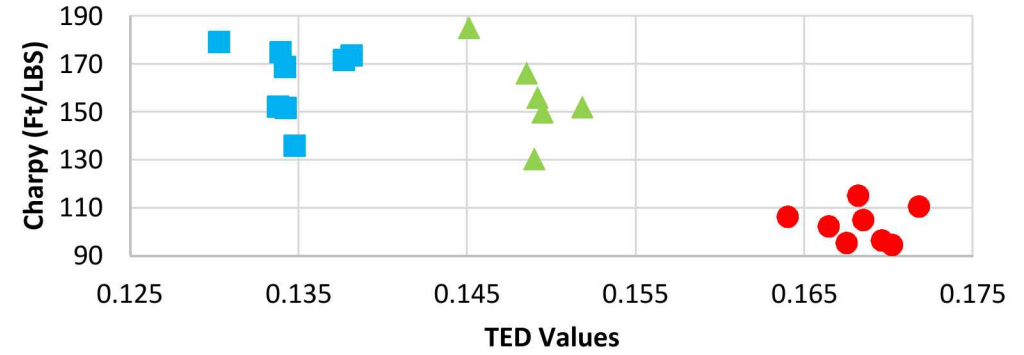
Charpy vs TED

Charpy vs TED Values Horizontal



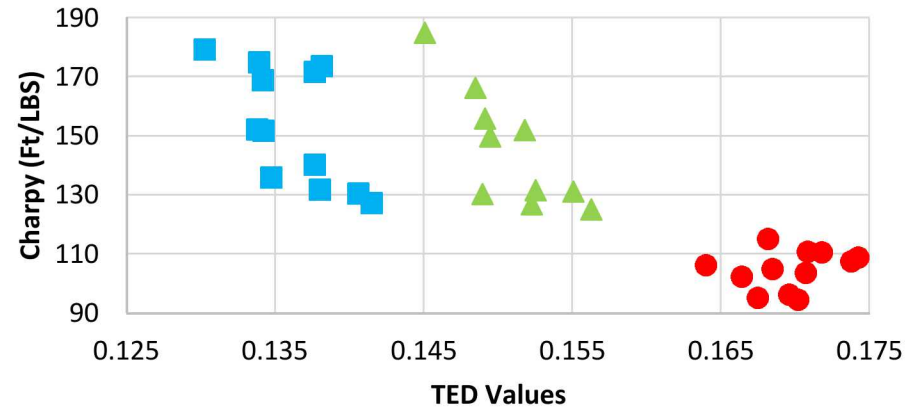
■ Low ▲ Nom ● High

Charpy vs TED Values Vertical



■ Low ▲ Nom ● High

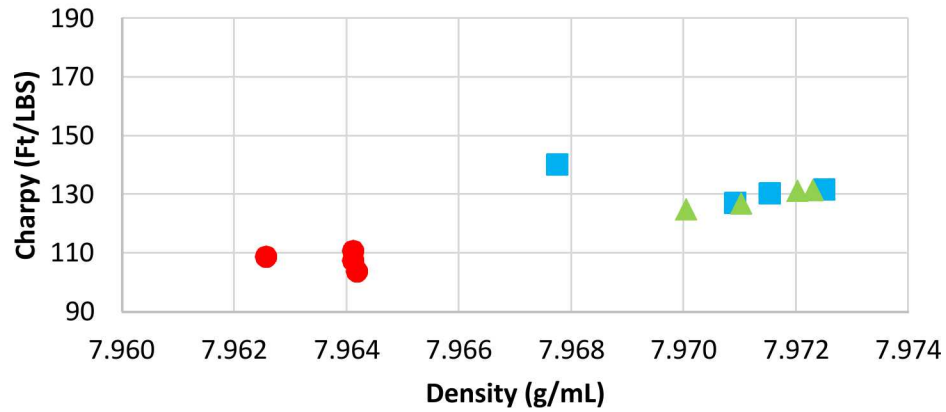
Charpy vs TED Values All



■ Low ▲ Nom ● High

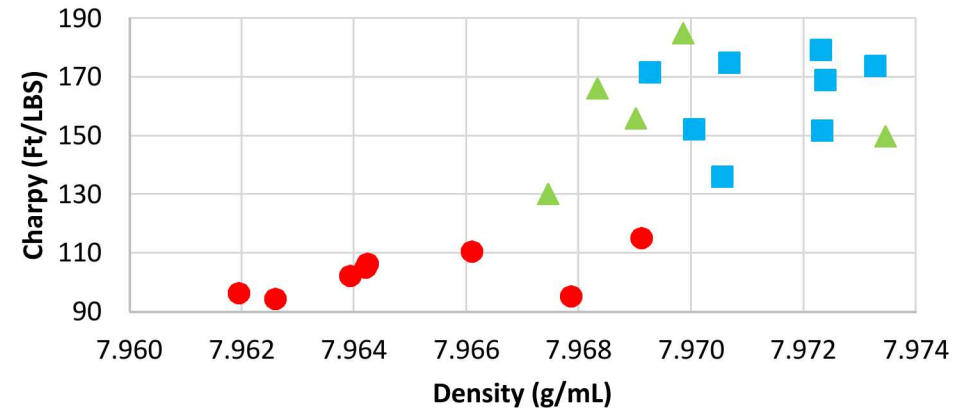
Charpy vs Density

Charpy Value vs Density Horizontal



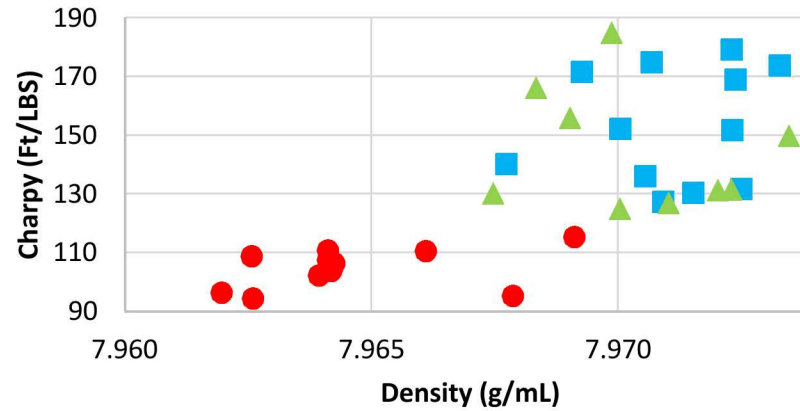
■ Low ▲ Nom ● High

Charpy Value vs Density Vertical



■ Low ▲ Nom ● High

Charpy Value vs Density All

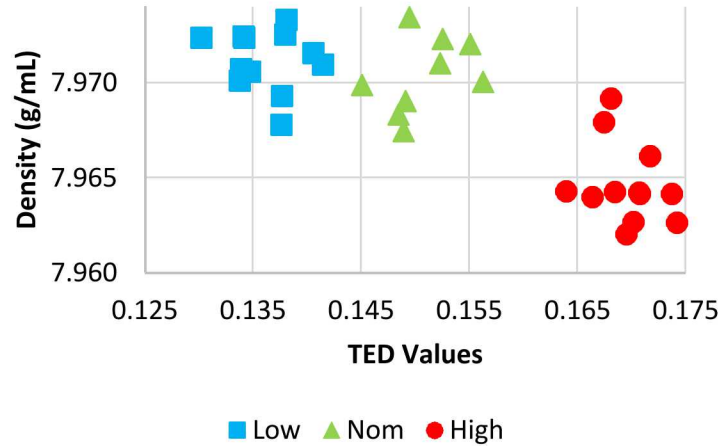


■ Low ▲ Nom ● High

Conclusions

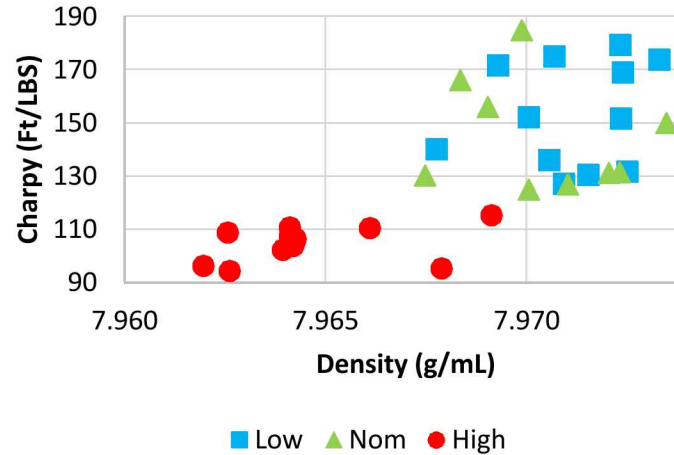
1

Density vs TED Value
All



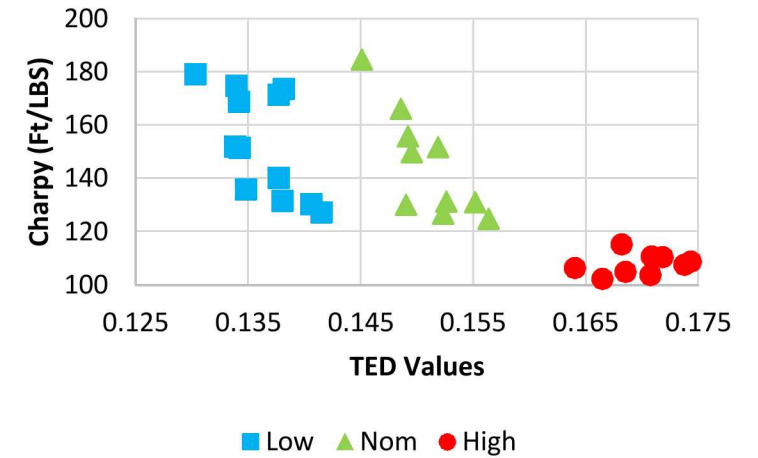
2

Charpy Value vs Density
All



3

Charpy vs TED Values
All



- 1: Highest energy input (TED) creates voids resulting in lower density.
- 2: Lower density results in weaker material (Charpy toughness).
- 3: Consequently, Charpy toughness can be predicted from TED values.

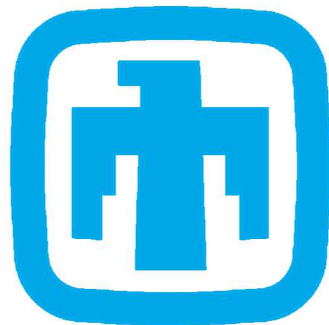
Acknowledgments

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- Aron Robins
- Zachary Casias



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