Review of A2: Organic Shape Projects

Engineering drawing for organic shapes
- seeing more and more organic shapes
- need regulations and reproducibility

Important if printing thin parts to look through it layer-by-layer

Discussion of Lattice article testing/differences between 2 studies

Beyer & Figueroa
more detailing
appreciate the density v. strength visualizations
images of the types of lattices structure variations
standardized / systematic
corners are stress points
- in CREO can blend the beams at really sharp corners

Abuedidda
easier read
fea/testing
changing experiment

Similarities/Other
testing was the same for both
fea justo for gyroid
different ways of measuring density
can we really compare lattice vs gyroid if there isn't consistent blending
interlayer bonding of lattice — from print direction, no notes on this

Takeaways
how do we compare one lattice to another, one technology to another?
Pareto front — anything that sort of sits on this line, technologies can't necessarily be better than the other

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A3 - Topological Optimization Getting Ready
- note that not in Boston area for the group email
- preform different from Cura because they have custom software that works for their printers vs. Cura
- need form 2 and form 3 files for TO

Design & Analysis of Lattice Structures for AM (2016) — Beyer & Figueroa

- AM has great potential in manufacturing of lighter parts by embedding cellular/lattice structures that consume less material while still distributing the necessary strength
- AM allows for complex parts with cellular and lattice structure implementation
- lattice structure geometry can be manipulated to deliver the level of performance required of the part
- tests concentrate primarily on the analysis of 3D printed polymer parts manufactured using PolyJet tech
- results show the behavior of test specimens with different cell structures under compression and bending load
- a lattice consists of a pattern repeated regularly in all directions —> pattern known as a unit cell
- lattice structure has less mass per volume than the solid part
- three major factors influence properties of cellular structures
  - (1) properties of material
  - (2) topology and shape of the cell
  - (3) relative density of the cellular structure
- objective of research was to explore different unit cells structures and their compressive and flexural properties
- two tests used to analyze the properties of various lattice geometries, compression & flexure
- main goal of the research was to observe the relative properties of each lattice compared to its relative density
- acquired data supported the established premise that hexagonal cells have relatively superior compressive properties
- flexure tests carried out in such a way that not much information was revealed about the relationship between structure and property
- focus of study was to compare relative properties of various structures with their relative densities
- second test series for aluminum specimens, but only compressive samples printed
- tetra structures generally result in higher yield strengths than the pyra structures except in extreme relative densities —> supported by both polymer and aluminum tests
- lower the relative density, more efficient the used material would become
- relative density of a structure may be increased and the relative strength increased, the data point would only get farther from the one-to-one ratio
- both kagome and tetra structures occupied higher relative densities and relative yield strengths than pyra, with the exception of a single point
- it was found that unit cells with vertical trusses returned results closest to that of solid cube, with hexagonal results returning the highest relative yield strengths
- demonstrated the practicality of aluminum lattice structures with yield strengths greater than half the relative density
- results suggest that at a certain point the linear relationship between the relative density and the relative strength may appear to plateau
- knowledge of optimal lattice configurations from a structural standpoint and well-defined design guidelines will enable design engineers to further reduce weight and increase structural efficiencies when designing for AM

$$\text{Engineering Stress } \sigma = \frac{F}{A}$$

$$\text{Engineering Strain } \varepsilon = \frac{\Delta l}{l_o}$$

$$\text{Maximum Flexural Stress for 4Pt. Flex Test } \sigma_{\max} = \frac{3Pa}{bh^2}$$

Yield stress (also known as yield strength) is the stress at which a material will transition from behaving elastically to plastically. It is typically determined using the 0.2% offset technique [32] discussed in more detail in Sec. 4.2.1.

The modulus of elasticity is the ratio of stress to strain while the material behaves elastically. This is graphically represented by the slope of the linear portion of the stress–strain curve (see Fig. 4) [34]. The higher the elastic modulus, the stiffer is the mate-

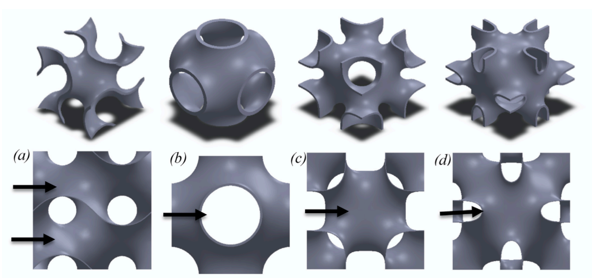
$$\text{Relative Density } \rho_r = \frac{\rho_l}{\rho_s} \quad (6)$$

The relative density is ρ_r. The density of the lattice structure (ratio of mass of structure divided by volume structure would occupy if it were solid) is given by ρ_l. Finally, ρ_s represents the density of

<u>Mechanical properties of 3D printed polymeric Gyroid cellular structures: Experimental and finite element study (2019) — Abueidda et al</u>

A gyroid is a member of the triply periodic minimal surfaces (TPMS) family

- the mechanical properties of gyroid-structures are investigated both experimentally and computationally
- 3D printing is used to fabricate polymeric gyroid-structure specimens made of PA 2200 at different relative densities
- the TPMS are surfaces with zero mean curvature and are characterized by local area minimizing which means any sufficiently small patch taken from the TPMS has the smallest area among all patches created under the same boundaries
- TPMS allow creating cellular structures having a higher surface-to-volume ratio than common strut-based cellular structures
- advantage of cellular structures is that their mechanical properties can be tailored to suit design requirements
- TPMS cellular structures can be used for bone tissue scaffolds
- this paper focuses on the mechanical properties of the sheet network type gyroid cellular structures, made of a polymeric base material with different relative densities
- FEA was performed to study the elasto-viscoplastic properties of these gyroid-structures using the Arruda-Boyce model under periodic boundary conditions
- the uniaxial modulus and compressive strength of the gyroid structures at different relative densities were obtained using COMSOL
- Cauchy stress in the linear elastic spring is calculated
- Conclusions:
  - gyroid structures were fabricated using 3D printing
  - TPMS structures including the gyroid structures features no joints or discontinuities and are thus able to minimize the effects of stress concentration
  - mechanical properties of gyroid structures under compressive loading were investigated through both experimental testing and FEA
  - results obtained from experimentation and computation in good agreement
  - when compared to Primitive-, IWP-, and Neovius-structures from previous studies, Gyroid-structure's compressive strength lands between the highest strength Neovius- and IWP-structures
  - gyroid-structure shows comparable properties to those of other TPMS structures and is a strong potential candidate for various tech applications



These represent one unit cell of the structure

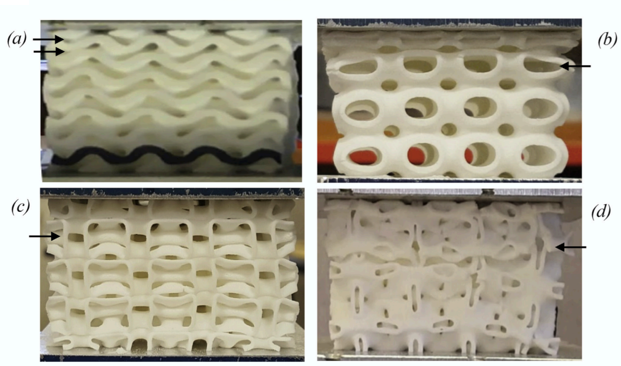


Fig. 8. Regions of localized deformations inside TPMS: (a) Gyroid-, (b) Primitive-, (c) IWP-, (d) Neovius-cells under compression [49].

Regions of localized deformations inside TPMS:
(a) Gyroid-
(b) Primitive-,
(c) IWP-,
(d) Neovius-cells
… under compression