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# Design of FDM Mesostructures for Thermoplastic Materials Under Manufacturability Constraints

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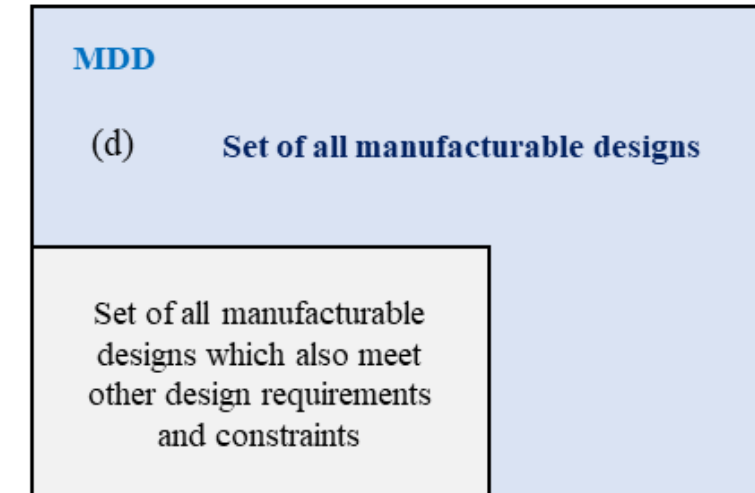
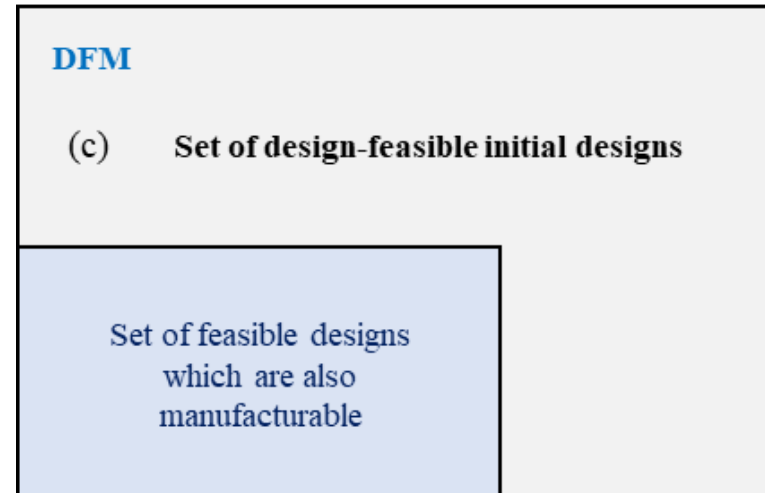
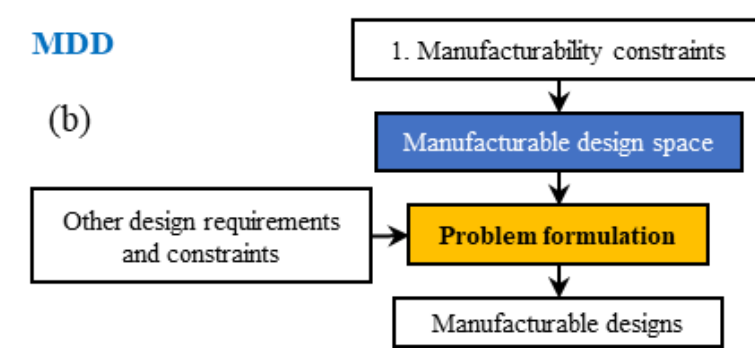
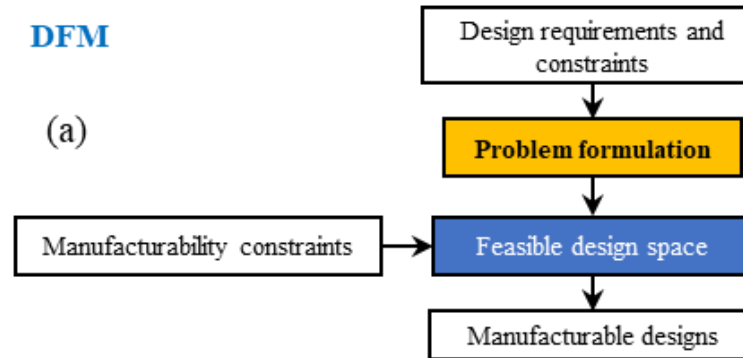
# Overview and Motivations

- **Design and manufacturing methods have rapidly advanced**
  - Design is now far more advanced than manufacturing methods
  - Additive manufacturing and advanced casting/molding methods
  - Algorithm-based design methods
    - topology optimization, generative design, optimal design
  - Design freedom, needs restrictions [1]
  - Additive manufacturing is both a help and a major cause of the problem [2-3]
- **Need a way to bridge the gap between advanced D & M**
  - Little control on processes and do not want to hurt advances in design
- **Previously: Design-for-manufacturing (DFM) methods were used**
  - Simple design, cheap materials, liberal tolerances, etc. [4-5]

# Manufacturability-Driven Design

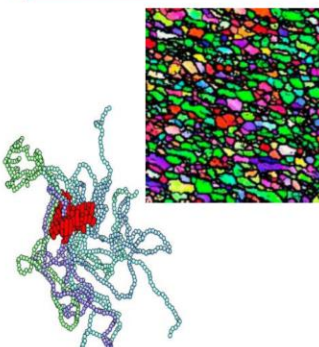
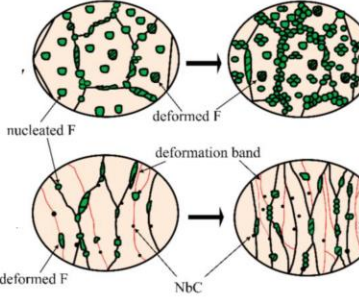
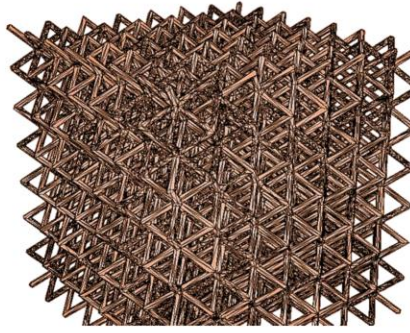

- **Manufacturability-Driven Design (MDD)** is a design approach where **manufacturability is the prime or co-prime requirement**

- Minimal restriction
- Drive new manufacturing processes
- Less dependent on expert intuition
- Process-induced material effects!

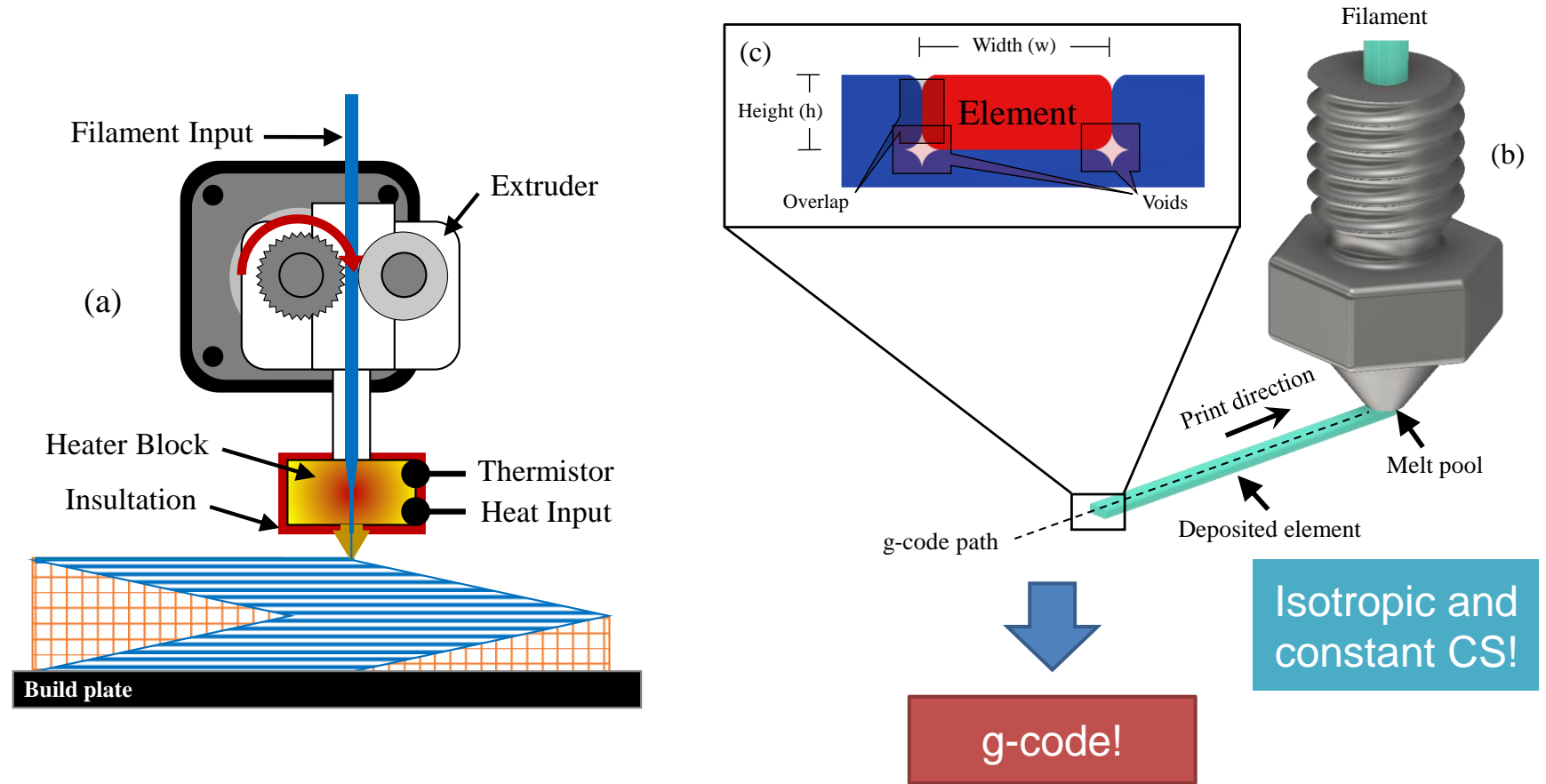
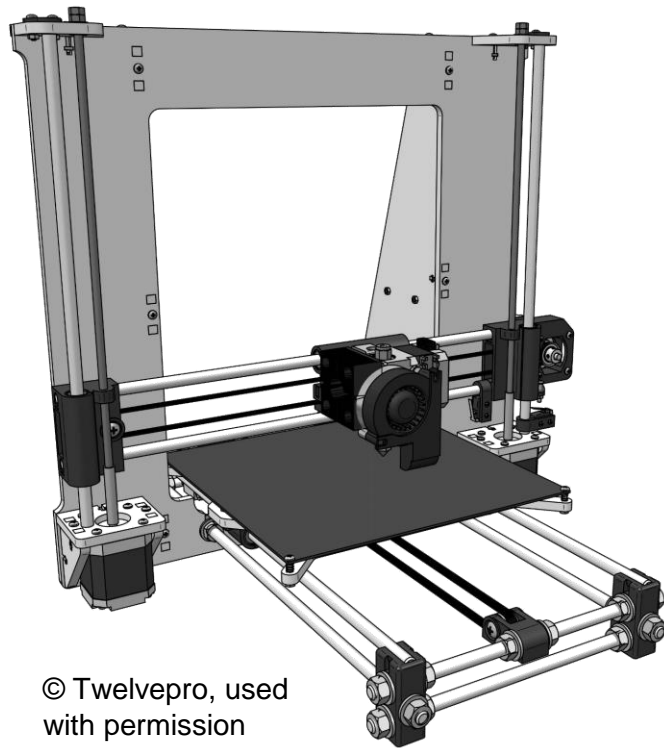


# FDM-Driven Structured Materials

- **AM Materials are naturally hierarchical**
  - Especially true for those built using scanning-type AM processes
- **New class of structured materials can be defined by combining MDD principles and the hierarchical nature of AM materials: Manufacturing Process-Driven Structured Materials (MPDSMs)**

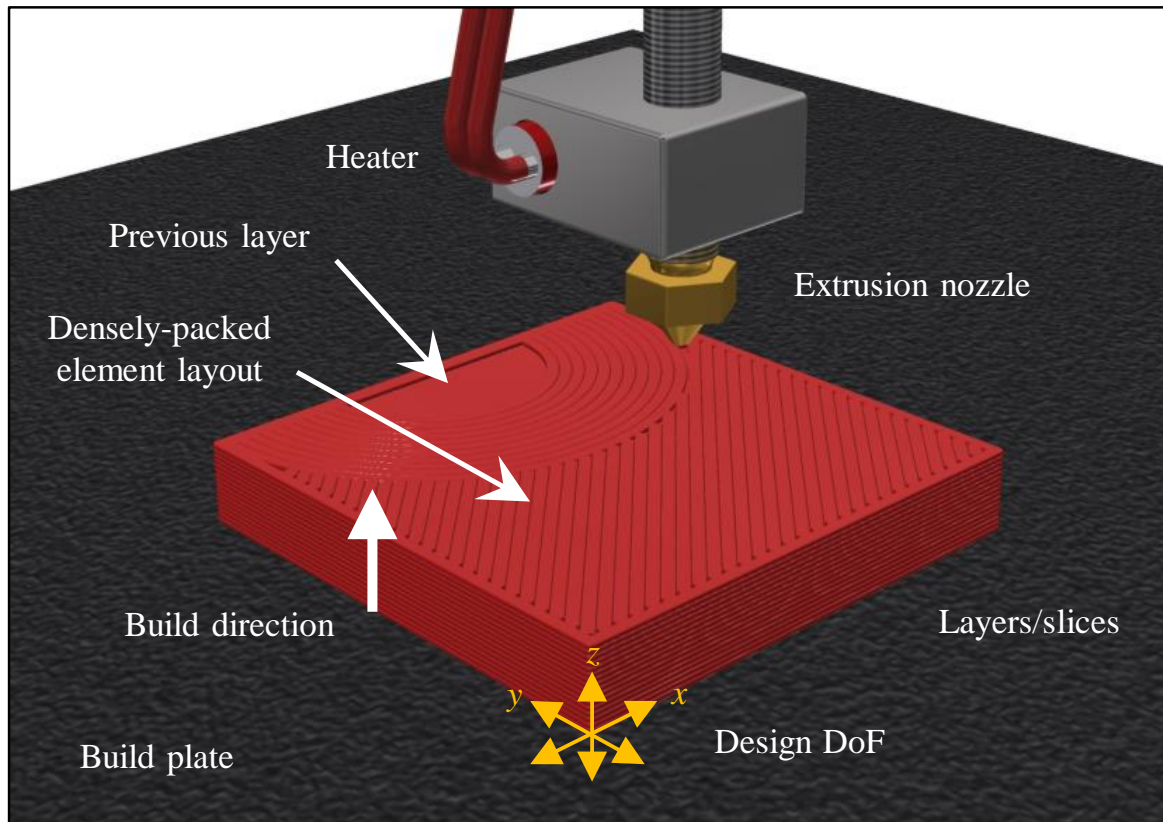
Natural material	<i>Source of Dominant Properties</i>		Structure and processing
			
Sub-microstructure	Microstructure	Mesostructure	Macrostructure
<ul style="list-style-type: none"> <li>❑ Natural material structure on atomic, crystal, or molecular level</li> <li>❑ May be influenced by processing conditions</li> <li>❑ <b>Examples:</b> Polymer chains, grain structure details in metals</li> </ul>	<ul style="list-style-type: none"> <li>❑ Structure observable using an optical microscope, heavily influential on macro-scale properties</li> <li>❑ Strongly influenced by processing conditions</li> <li>❑ <b>Examples:</b> Porosity, metal grain layout, scan structure in 3-D printed materials</li> </ul>	<ul style="list-style-type: none"> <li>❑ Designed or patterned structure, may be generated by element layout or designed inclusions/defects/voids</li> <li>❑ Solid, homogeneous materials do not have a mesostructure</li> <li>❑ <b>Examples:</b> Honeycomb structure, metamaterial, unit cell-based lattice</li> </ul>	<ul style="list-style-type: none"> <li>❑ In design, typically the “useful level”</li> <li>❑ Generally the final component or product that is to be made from the designed material</li> <li>❑ For homogeneous solid materials, microstructure drives macrostructure properties (no mesostructure)</li> </ul>

# FDM-Driven Structured Materials

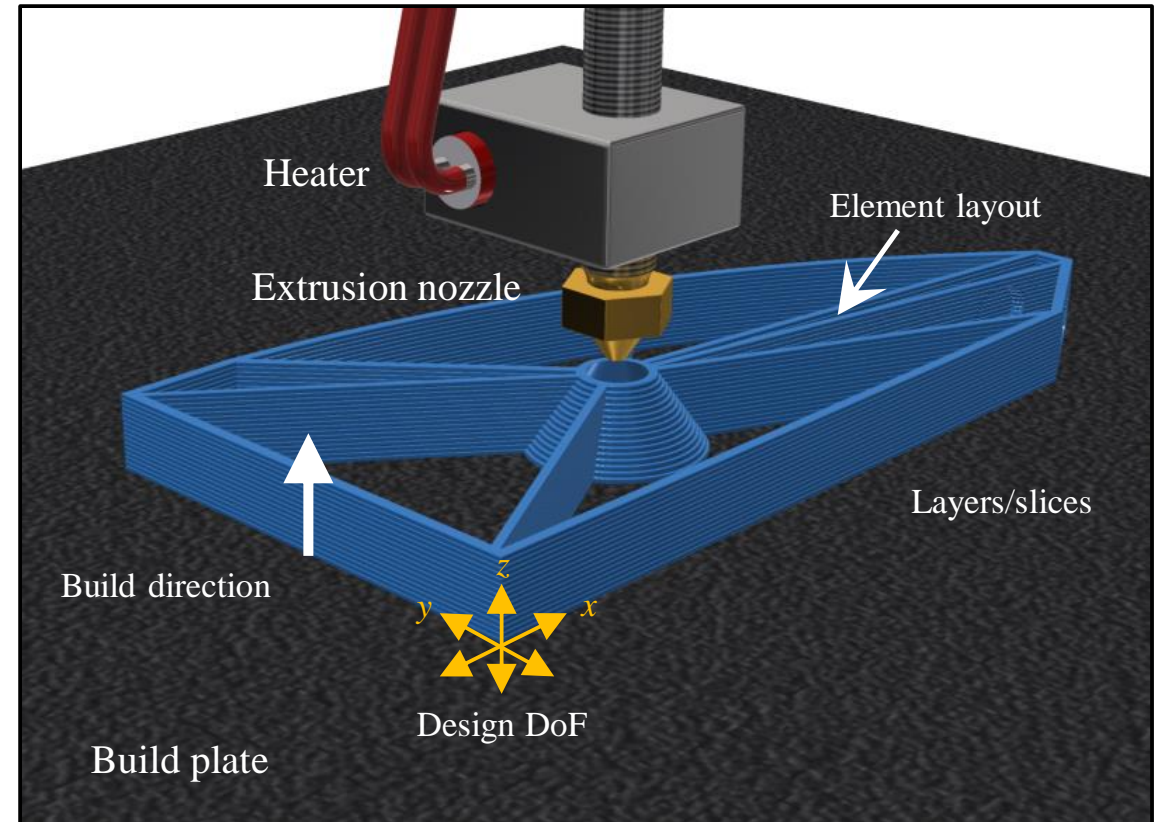


# FDM-Driven Structured Materials

(e) High-density FDM-based 3-D MPDSM

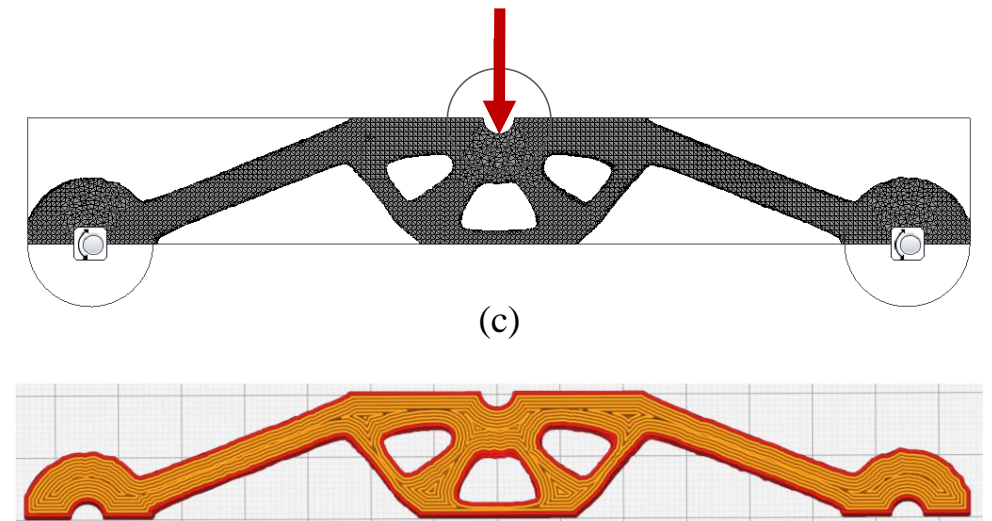
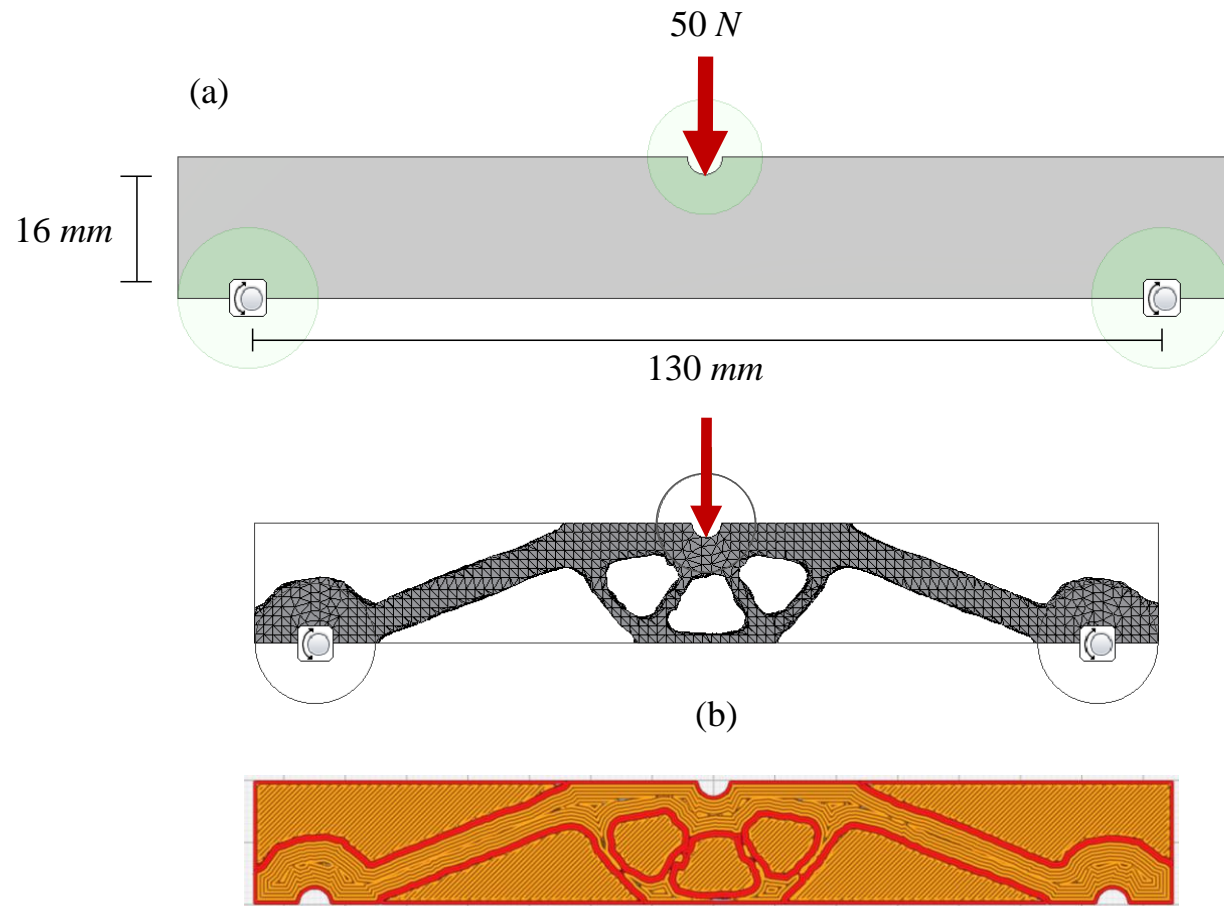


(d) Low/medium-density FDM-based 3-D MPDSM

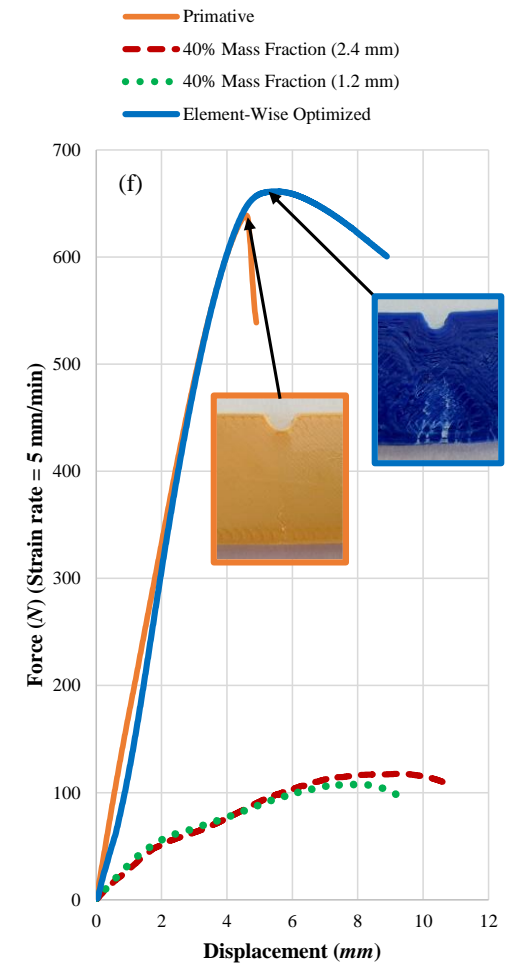
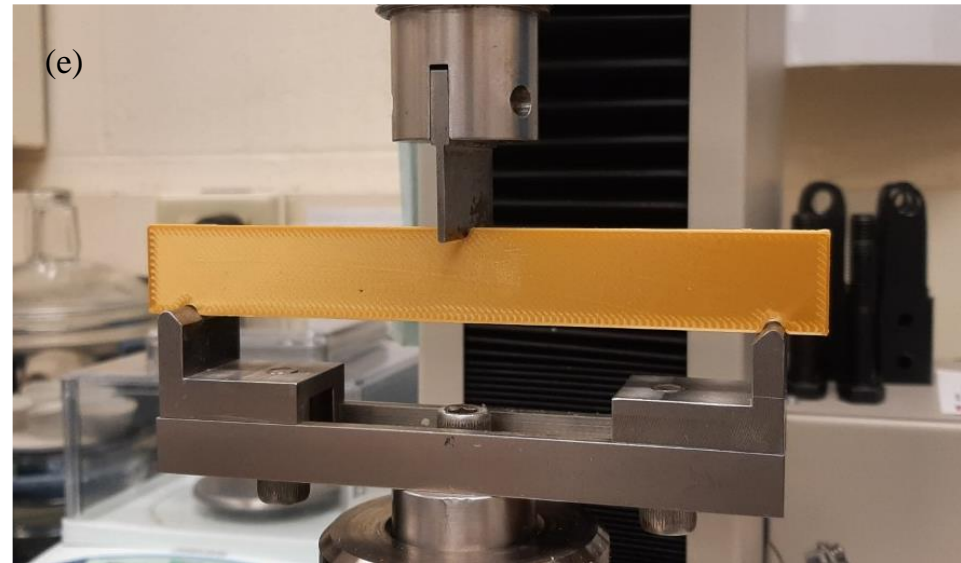




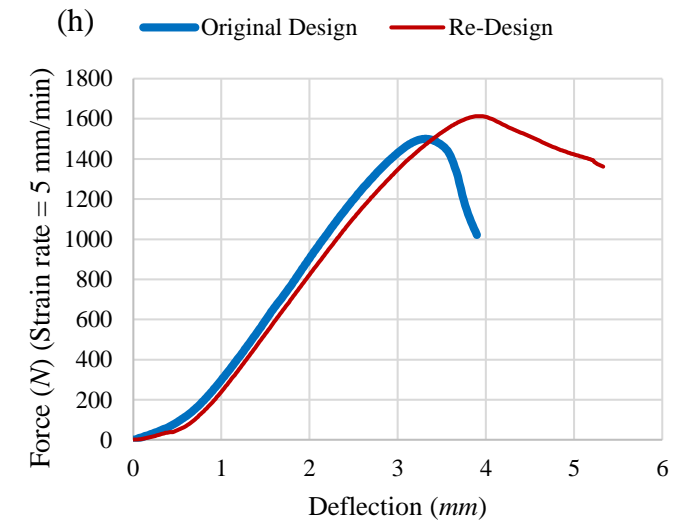
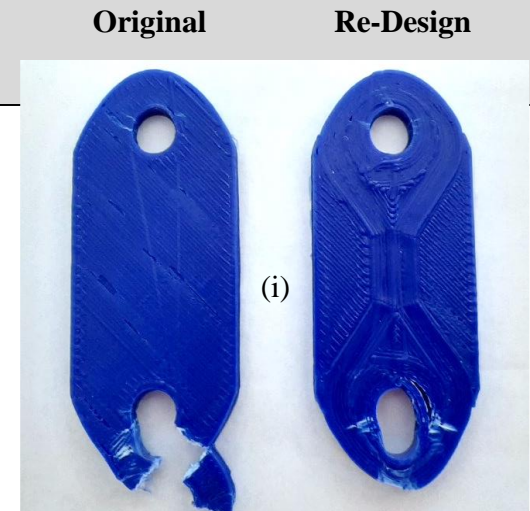
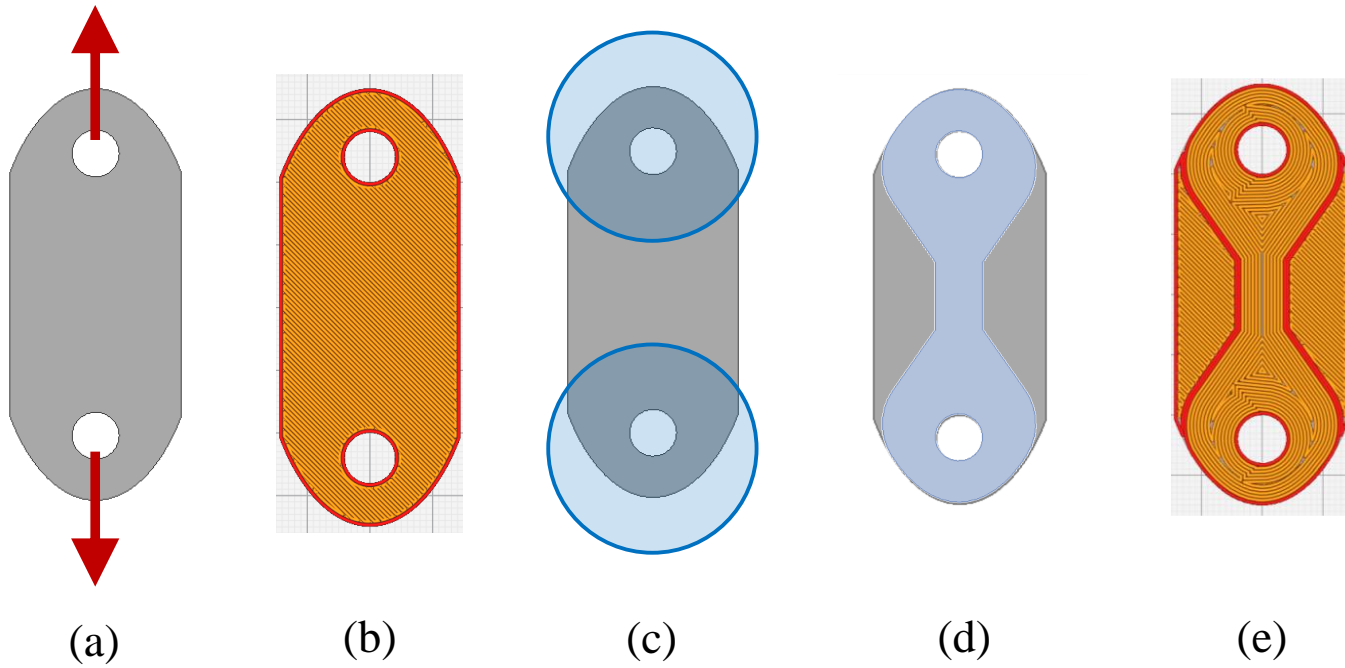
# Case Study I



# Case Study I



# Case Study II



# Closing Remarks



# References

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