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Mechanical Characterization of TPMS Structures Fabricated via SLA 3D Printing using Tough Resin: Influence of Geometry on Performance

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INTRODUCTION & AIM

TPMS structures are ideal for lightweight, energy-absorbing applications, particularly in engineering and medical fields, due to their ability to optimize stress distribution while maintaining low density. Advances in SLA 3D printing and tough engineering resins enable precise fabrication of these complex geometries. This study evaluates the mechanical behavior of six TPMS structures—gyroid, primitive, diamond, lidinoid, neovious, and splitP—under compression, focusing on the effects of wall thickness and geometry while maintaining consistent dimensions and porosity.

METHOD

Six (6) TPMS designs were fabricated using SLA 3D printing technology, ensuring high precision and surface quality. Each structure had dimensions of 70×70×70 mm³ with a porosity of 75%, providing a controlled environment to study mechanical behavior. A tough engineering resin was selected for its excellent mechanical properties, making it suitable for applications such as engineering prototypes, mechanical aids, fixtures, and medical devices.

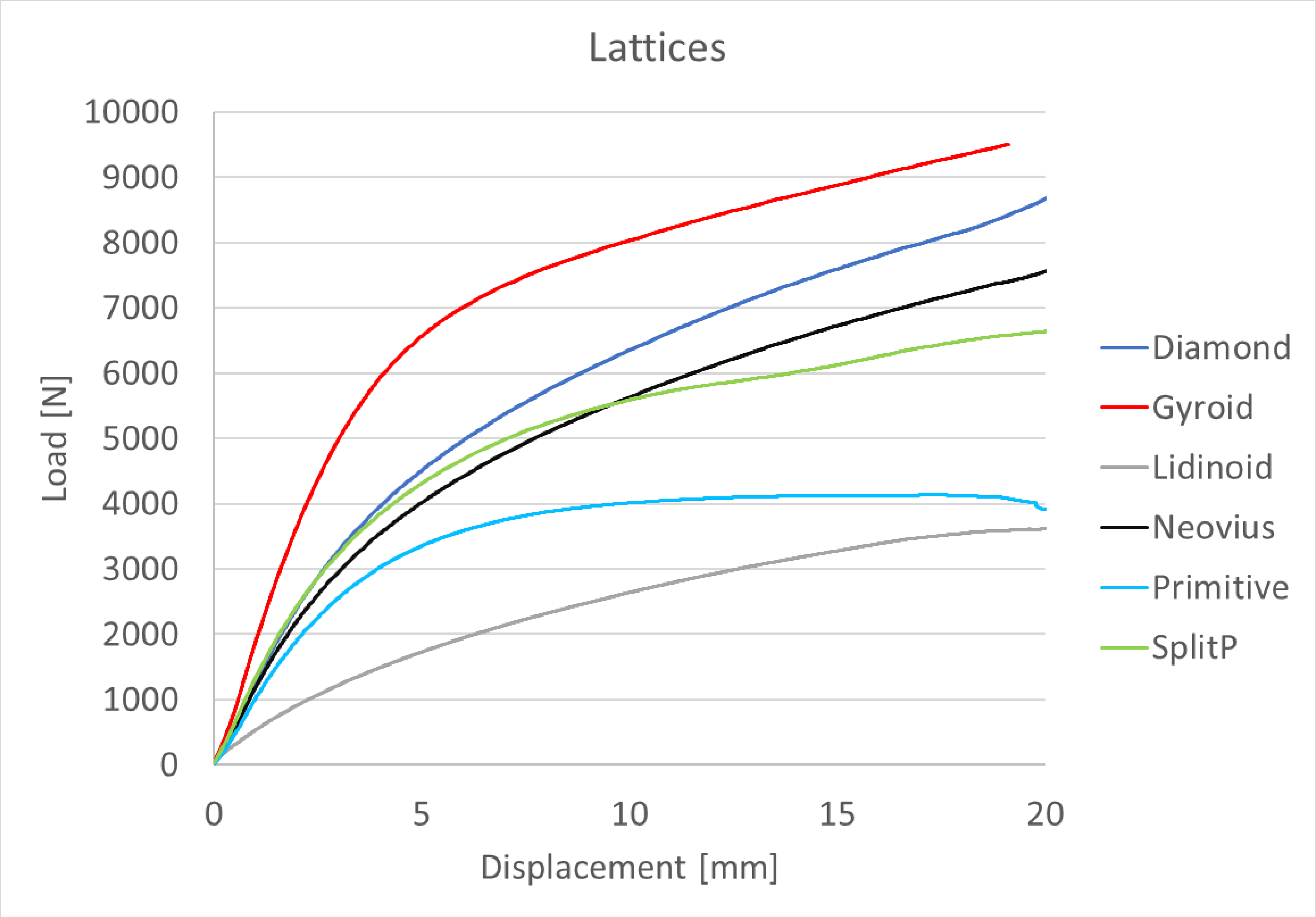
Compression tests were conducted at a deformation rate of 2 mm/min to examine the stress-strain responses of the structures. Wall thickness varied among the designs, with values ranging from 0.31 mm for neovious to 2.32 mm for gyroid, allowing for a detailed analysis of how wall thickness and geometry impact mechanical performance.

Gyroid Diamond Primitive

SplitP Neovius Lidinoid

RESULTS & DISCUSSION

The stress-strain responses showed clear differences in the mechanical behavior of the six TPMS structures. In the elastic zone, stress increased in the following order: lidinoid, primitive, neovious, splitP, diamond, and gyroid. While thicker walls generally resulted in higher stress, geometry had a significant influence on performance.Neovious, despite having the thinnest walls (0.31 mm), ranked fourth in stress, illustrating that wall thickness alone cannot fully predict mechanical behavior. Similarly, splitP and diamond exhibited nearly identical stress-strain curves, indicating comparable mechanical properties despite differences in wall thickness. Gyroid, with the thickest walls, displayed the highest stress in the elastic zone, aligning with the general trend of increased stress for thicker walls.These results highlight the complex interaction between geometry and wall thickness in determining the mechanical properties of TPMS structures.



CONCLUSION

This study demonstrates that both wall thickness and geometry significantly influence the mechanical behavior of TPMS structures. While thicker walls generally lead to higher stress in the elastic zone, the superior performance of neovious suggests that geometry can sometimes outweigh the effects of wall thickness. By leveraging advanced TPMS designs and tough engineering resins, this work highlights the potential to create lightweight, robust components for various applications, including engineering and medical fields.

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