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Material Solutions for Impact Protection: Comparative Insights on Foams and Lattices

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Abstract

Foams have traditionally been the material of choice for protection applications. However, lattices have recently emerged as a competitive alternative, and their use is steadily increasing. This paper presents a quantitative analysis of researches published in the first quarter of the 21st century. Statistical findings reveal a growing trend of replacing foams in protective devices with lattice structures. This shift is primarily driven by the improved ability to control absorption properties during the design phase, enabling the tailoring of lattices to specific applications. The paper also highlights current and emerging uses that demand simultaneous energy absorption and impact absorptions. This study on current research trends reveals where industry and funding agencies are investing and points to future applications of advanced materials in protective industries.

Keywords: Energy absorption; Impact absorption; Lattice; Foam

Introduction

Foams have long been a common choice for the light-weight core of sandwich structures [1], benefiting from their absorption capabilities [2]. However, recent advancements in 3D-printing technologies have enabled engineers to fabricate intricate lattice structures [3], marking the beginning of a new era in materials for protection applications. Compared to foams, lattices exhibit superior strength, largely due to their reduced susceptibility to localized yielding [4]. Their characteristic stress–strain curves display a distinct linear elastic region followed by a relatively long, flat plateau, making them more effective for energy absorption [5]. Flexibility in design is the feature which allows lattices to be compatible with the needs of a particular application [6].

Gibson and Ashby [7] developed a design approach for foams used in the packaging industry, based on the stress–strain characteristic diagram obtained from compression test. Then, this diagram is converted to impact-energy absorption diagram. Vaziri Sereshk and Faierson [8] introduced a compression test setup for lattice structures, detailing the sample configuration, testing conditions, and data analysis methods. They further extended Ashby's design methodology to apply to metallic lattices.

The energy absorption capabilities of metallic lattices have been extensively studied in the literature [9]. However, impact absorption—particularly in protection-related applications—warrants further investigation. This is especially critical in areas such as packaging and safeguarding humans from injury during high-impact events. For instance, in military armored vehicles, protecting occupants from air blasts and land mine explosions (including improvised explosive devices, or IEDs) remains a major concern. Even when blast absorbers are effective enough to absorb significant amounts of energy and preserve the structural integrity of the hull, the resulting blast pressure can still transfer considerable momentum to the vehicle, causing severe life-threatening injuries such as traumatic brain injury and spinal cord compression [10,11]. This highlights the importance of absorbing impact. Lattice structures are increasingly utilized in these scenarios. Other examples include crush boxes in civilian vehicles for low-velocity impacts, lattice liners in athletic helmets [12], protection systems for ship hulls and offshore structures [13], sacrificial layers for NASA reentry capsules [14], and military airdrop cushioning systems [15]. This study presents a quantitative analysis to assess the current state of cutting-edge research, highlighting where industry and funding agencies are directing their investments. These trends offer valuable insight into the future applications of advanced materials in protection-focused industries.

Energy and Impact Absorption Researches

Google Scholar search engine is used to compare the trend and number of research and publication for lattice structures and foams. The result is summarized as bar charts in Figures 1(a) and 1(b) for energy and impact related research published before the year 2025.

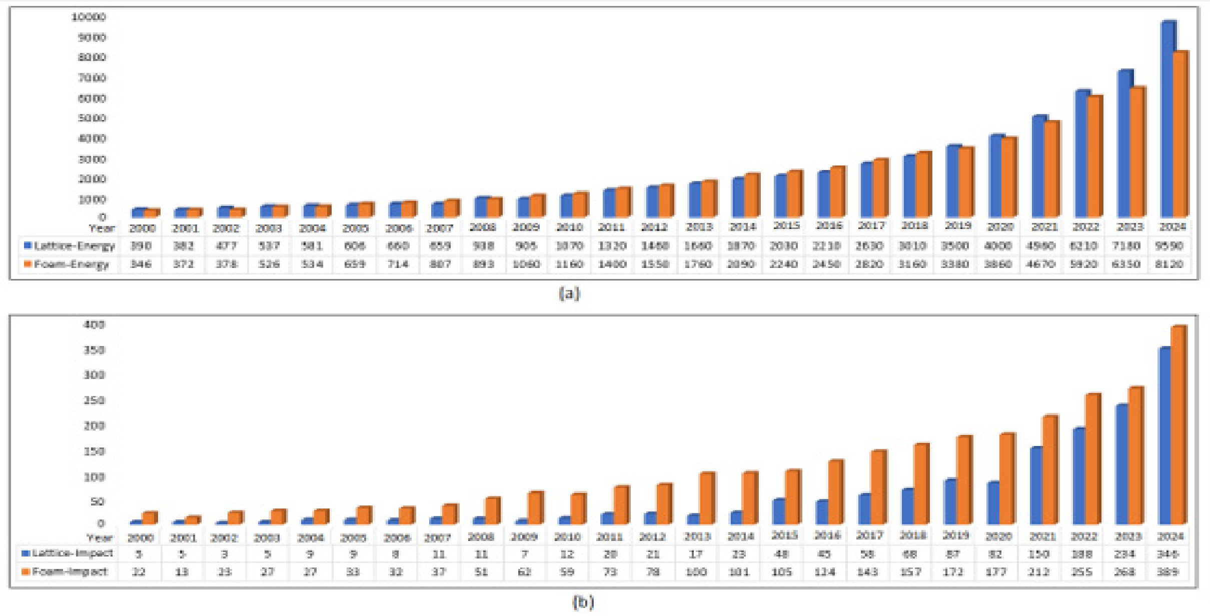

Figure 1: The amount of research conducted to discuss energy (Figure. 1(a)) and impact (Figure. 1(b)) absorptions of foam and lattice cellular materials for the first quarter of the 21st century.

Discussion

It indicates that for the first quarter of the 21st century, the amount of research conducted to discuss energy absorption of both cellular materials is growing at the same rate. However, lattice is taking the lead and widening the gap in the last five years. This may be attributed to the ability to modify cell topology during the design phase of lattices, in contrast to the inherently irregular and random geometry of foam cells. While the maximum energy absorption per unit weight is typically achieved at a relative density between 0.2 and 0.3, the lattice topology can significantly influence the magnitude of the peak for absorbed energy through different collapse mechanisms [16]. This represents a key advantage of lattices over foams.

It demonstrates that impact absorption behavior of these two types of cellular materials has been studied far less extensively compared to their energy absorption characteristics. For approximately every 30 studies on energy absorption, there is only one focused on impact absorption. This area remains underexplored and warrants more in-depth investigation. It shows that foams have traditionally been the preferred choice for impact absorption. However, the use of lattices for this purpose has been increasing, quickly narrowing the gap. One reason can be the outcome of recent studies demonstrating superiority of lattices due to offering more design features including gradient density through the structure [17]. This allows greater control over impact absorption.

Conclusion

The comparison of research trends shows that while both foams and lattices have been widely studied for energy absorption, lattice structures have gained increasing attention in recent years due to their tunable geometry and superior performance through varied collapse mechanisms. In contrast, impact absorption remains significantly underexplored, with far fewer studies dedicated to this area. Although foams have traditionally dominated impact-related applications, recent advancements highlight the growing potential of lattices, which offer greater design flexibility to control impact response. These findings highlight the strong potential of lattices as a preferred material for protection-focused applications, encouraging further funding and research to fully explore their advantages.

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Conflict of Interest

The author declares no conflict of interest.

References

1. Faris T (2021) Sandwich Structures for Energy Absorption Applications: A Review. Materials 14(16): 4731.
2. Santosa SP, Arifurrahaman F, Izzudin MH, Widagdo D, Gunawan L (2017) Response analysis of blast impact loading of metal-foam sandwich panels. Procedia Engineering 173: 495-502.
3. Vaziri Sereshk MR, Faierson E (2022) Study of defects and dimensional accuracy to determine manufacturability thresholds for laser powder bed fusion of Ti-6Al-4V lattices. International Journal of Advanced Manufacturing Technology 123:3795-3806.

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4. McKown S, Shen Y, Brookes WK, Sutcliffe CJ, Cantwell WJ, et al., (2008) The quasi-static and blast loading response of lattice structures. International Journal of Impact Engineering 35(8): 795-810.

5. Al-Saedi DSJ, Masood SH, Faizan-Ur-Rab M, Alomarah A, Ponnusamy P (2018) Mechanical properties and energy absorption capability of functionally graded F2BCC lattice fabricated by SLM. Materials and Design 144: 32-44.

6. Vaziri Sereshk MR, Faierson EJ (2024) Development of characteristic diagram for optimum energy and impact absorption of lattices. International Journal of Advanced Manufacturing Technology 132: 4663-4676.

7. Gibson LJ, Ashby MF (1997) Cellular Solids: Structure and Properties. Cambridge University Press.

8. Vaziri Sereshk MR, Faierson EJ, Nelson BD (2025) Design of experiment and analysis of deformation for compression test of lattices using digital image correlation. International Journal of Advanced Manufacturing Technology 136: 1131-1147.

9. Korkmaz ME, Gupta MK, Robak G, Moj K, Krolczyk GM, et al., (2022) Development of lattice structure with selective laser melting process: A state of the art on properties, future trends and challenges. Journal of Manufacturing Processes 81: 1040-1063.

10. Ramasamy A, Masouros SD, Newell N, Hill AM, Proud WG, Brown KA , Bull AMJ, Clasper JC (2011) In-vehicle extremity injuries from improvised explosive devices: current and future foci. Philos Trans R Soc Lond B Biol Sci 366(1562): 160-70.

11. Rigby SE, Fay SD, Clarke SD, Tyas A, Reay JJ, et al., (2016) Measuring spatial pressure distribution from explosives buried in dry Leighton Buzzard sand. International Journal of Impact Engineering 96: 89-104.

12. Farajzadeh Khosroshahi S, Duckworth H, Galvanetto U, Ghajari M (2019) The effects of topology and relative density of lattice liners on traumatic brain injury mitigation. Journal of Biomechanics 97: 109376.

13. Armanfar A, Tasmektepligil AA, Kilic RT, Demir S, Cam S, et al., (2024) Embedding lattice structures into ship hulls for structural optimization and additive manufacturing. Ocean Engineering 301: 117601.

14. Zhang AS (2022) Design of Impact-Resistant Tensegrity Landers. University of California, Berkeley.

15. Christopher JD, Arjona E, Fotso H, Hemingway G, Boll C, et al., (2024) Developing an Autonomous, Arrested, Protected, Covert Small Payload Delivery Technique from an Unmanned Aerial System. AIAA SCITECH 2024 Forum, Orlando, FL.

16. Vaziri Sereshk MR, Faierson EJ (2024) Improvement in Energy Absorption of Additively Manufactured Lattice Structures after Modification of Collapse Mechanisms. International Journal of Advanced Manufacturing Technology 130: 1617-1633.

17. Vaziri Sereshk MR, Faierson EJ (2025) Concept development for innovative functionally graded lattice structures to absorb desired energy and impact. Advances in Manufacturing.

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