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ADDITIVELY MANUFACTURED DUAL-FACED STRUCTURED FABRIC FOR SHAPE-ADAPTIVE PROTECTION

HP INC

Additively Manufactured Dual-faced Structured Fabric for Shape-adaptive Protection

Abstract:

Here we disclose a novel dual-faced structured fabric and its design method. The dual-faced structuredffabric consists of 3D re-entrant unit cells interlocked in a chain mail structure with different unit cell arrangements on its top and bottom surfaces. The combined design of the energy-absorbing re-entrant unit cells and their unique topological interlocking synergistically strengthens the structured fabric and makes it superior to a wide range of materials proposed for wearable applications. The flexible structured fabric fabricated from polyamide 12 (PA12) by the Multi Jet Fusion (MJF) technique demonstrates high specific energy absorption and specific strength of up to 1530 J/kg and 5900 N·m/kg, respectively, together with an excellent recovery ratio of around 80%, thereby overcoming the strength–recoverability trade-off. The dual-faced structured fabric can be processed by other materials and printing techniques. For example, the structured fabric can be printed using a superalloy for ultra-high-strength and/or high-temperature applications. The combined design in the unit cells and their interlocking would broaden the application prospects of fabric-based materials toward shape-adaptive protection such as medical supports and precision component packaging, as well as military and aerospace safety equipment.

Description:

Fabric-based materials, including woven or interlocking structures, are promising for high-performance wearable applications but are currently restricted by their deficient mechanical properties. Developing a flexible lightweight material with high strength, deformation recoverability, and energy absorption capacity will be an important step towards next-generation shape-adaptive protection. Although the recent work has successfully utilized additive manufacturing to obtain a structured fabric with tunable bending modulus, the mechanical properties of this structured fabric are deficient for high-performance wearable applications requiring high specific strength and energy absorption. Therefore, it is worthwhile to explore novel structured fabric and design methods to extend the application prospects of fabric-based materials to shape-adaptive protection.

Here, we leverage the sample structural freedom offered by additive manufacturing to design and fabricate a dual-faced structured fabric consisting of 3D re-entrant unit cells interlocked in a chain mail structure with different unit cell arrangements on its top and bottom surfaces. The new structured fabric is disclosed in Figure 1. The designed structured fabric consists of 3D re-entrant unit cells topologically interlocked in a staggered chain arrangement (Figure 1a). The re-entrant unit cell is defined by three geometric parameters, including the strut diameter d, edge length a, and re-entrant distance m. The structured fabric has different unit cell arrangements for the top and bottom surfaces, resulting in a dual-faced feature (Figure 1b). The printed sample is highly flexible, and can be folded, draped, and furled (Figure 1c). The furled fabric can be further compressed for storage with a final size reduction of 30%. After a vacuum pressure has been applied, the confined fabric can withstand a load of more than 25 times its own mass (top right panel of Figure 1c).

The dual-faced structured fabrics were printed by an HP Jet Fusion 3D 5200 printer (HP Inc., USA) using PA12 powder with an average size of ~66.2 µm and a peak melting temperature of 188.4 °C. The 'Balanced' print mode was selected for the printing of structured fabrics using a recommended virgin/used powder mixture ratio of 20:80. The thickness of the printing layer was 80 μm. After fabrication, all structures were subjected to a sandblasting treatment with glass beads (average size of ~90 μm) at a pressure of ~0.4 MPa. Finally, the post-processed parts were encased within an envelope composed of a thermoplastic polyurethane (TPU) film with a thickness of 0.1 mm. A vacuum confining pressure was then applied to jam the structured fabric, thereby improving the mechanical properties of the structured fabric.

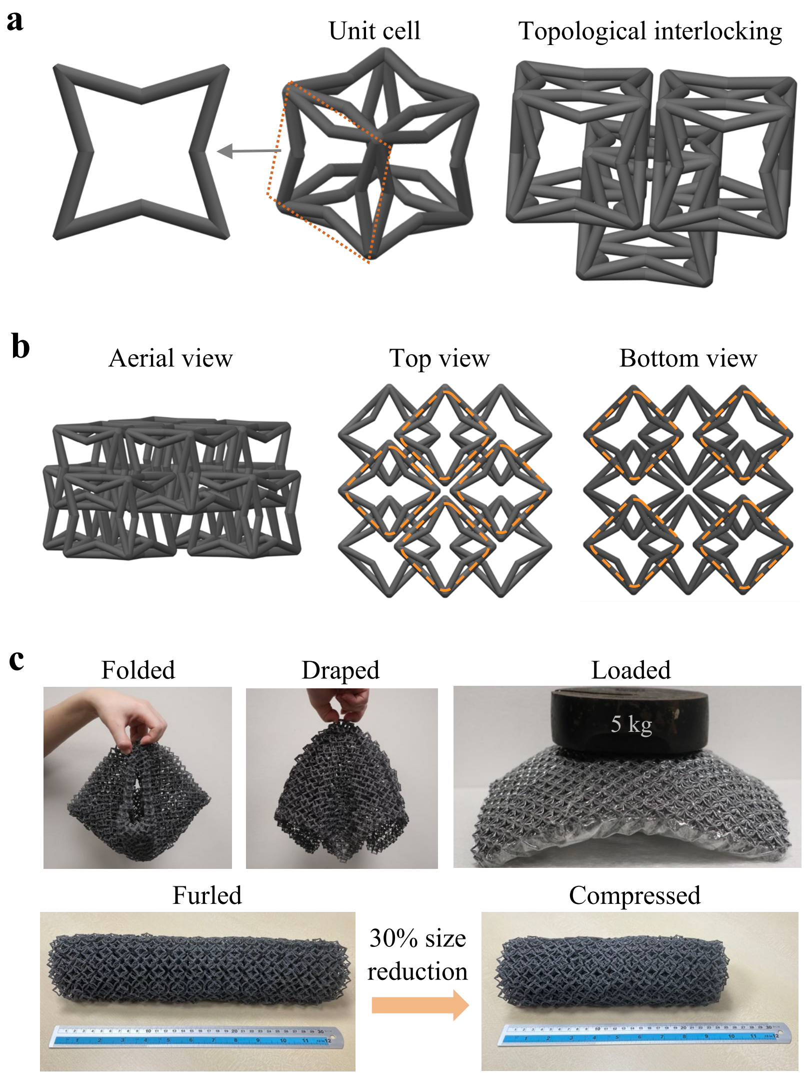

Figure 1. Design and prototype of the dual-faced structured fabric. **a,** Schematic illustration of the 3D re-entrant unit cell in the dual-faced structured fabric and its topological interlocking. **b,** three views of the structured fabric showing the different unit cell arrangements on the top and bottom surfaces. **c,** Different configurations of the structured fabric, indicating that it can be folded, draped, furled, and compressed in its flexible state, and that it can withstand load under vacuum confining pressure.

Based on the novel dual-faced structured fabric and its design method, you will:

A) Obtain a dual-faced structured fabric possessing the best mechanical performance compared with the reported structured fabric and other designed structured fabrics and being competitive with most existing energy-absorbed materials or structures.

B) Tune the specific strength, specific energy absorption, and specific bending modulus of the dual-faced structured fabric by using different vacuum confining pressures around its boundaries, thus overcoming the problem that the mechanical properties of the materials or structures are fixed once they are fabricated.

C) Achieve a much higher specific strength, specific energy absorption, and specific bending modulus for the structured fabric without sacrificing the high recovery ratio under a small vacuum confining pressure.

D) Not only solve the problem that the geometric shape of energy-absorbing materials or structures is fixed once they are fabricated, but also extend the structured fabric to human body protection due to its lightweight and shape-adaptive features and outstanding energy absorption capacity.

E) Fabricate the structured fabric with other additive manufacturing techniques using other materials as well, in addition to the MJF technique using PA 12 material, thereby being readily applicable for shape-adaptive protection in the civil and defence fields, such as medical support and precision component packaging, as well as military and aerospace safety equipment.

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