Mechanical Properties of SLA-Fabricated Octahedral Lattice Structures (Postprint)

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Abstract

Octet lattice structures with relative densities of 11.3%, 19.5%, 24%, and 27.9% were fabricated using V5 tough resin via SLA 3D printing technology, and subsequently subjected to UV curing treatment. The mechanical properties of the octet lattice structures before and after curing were evaluated through compression testing. The results demonstrate that the compressive modulus, compressive strength, specific energy absorption, dimensionless normalized stiffness, and dimensionless normalized strength of the octet lattice structures all increase with increasing relative density. When the relative density was increased from 11.3% to 27.9%, the compressive modulus of both non-cured and cured octet lattice structures increased by approximately 3.5 times, while the compressive strength increased by approximately 3 times. At the same relative density, the cured octet lattice structures exhibited higher compressive modulus and compressive strength, with the post-curing compressive modulus being approximately 4 times that of the non-cured structures, and the compressive strength approximately 5 times that of the non-cured structures. Furthermore, as the relative density increased, the increasing trend in specific energy absorption of the cured octet lattice structures outperformed that of the non-cured octet lattice structures.

Full Text

Introduction

The concept of lattice structures was first proposed by researchers from MIT and Cambridge University [MATH_{0026}]. After years of research and development both domestically and internationally [MATH_{0027}], these structures have been widely applied in aerospace, vehicle and shipbuilding, marine engineering, and other fields [MATH_{0028}]. The rapid advancement of 3D printing technology has further facilitated the development and application of lattice structures, making research on 3D-printed lattice structures a prominent focus in contemporary engineering. Numerous scholars worldwide have conducted in-depth investigations into lattice structures fabricated via 3D printing. G- et al. [MATH_{0029}] analyzed the mechanical properties of such structures through numerical simulation and experimental testing, with both approaches demonstrating excellent energy absorption characteristics. Ding Li et al. [MATH_{0005}]*!i)[MATH_{0030}] have also contributed significantly to this area.

Experimental Methods

The schematic diagram of the octet lattice structure unit cell is shown in Figure [MATH_{0031}]. The structure comprises [MATH_{0032}] rod elements, each featuring a square cross-section [MATH_{0033}]*2[MATH_{0034}]#Schematic diagram of octet lattice structure unit cell ,;@* [MATH_{0035}].

Mechanical property testing was first performed on the ‘1’ tough photosensitive resin according to national standard M’ X]%130 4%&&W [MATH_{0036}]. Certain octet lattice structures underwent UV curing [MATH_{0037}], with specimens placed in a 3& r ' UV curing chamber [MATH_{0038}]. The tensile speed was maintained at % 99X9;?%. Using Equation ! [MATH_{0039}], the true stress-strain curve for the ‘1’ tough photosensitive resin is presented in Figure % [MATH_{0040}]. The conversion follows &0d&Q! [MATH_{0041}] e,Q” , where &&0 denotes true stress, &Q denotes engineering stress, #0 denotes true strain, and #Q denotes engineering strain. Table [MATH_{0042}]#]->DK->C)D>(R9-FO:?;F:)TK(T-KD;->(R ‘1 D(C@O K->;? R(KC?FCK-E :?E FCK-E %0 “*i octet lattice structures [MATH_{0043}] were analyzed to compare mechanical properties before and after curing. The test durations were %%1 s[MATH_{0044}] and 3*% s[MATH_{0045}]. As shown by the curves in Figure % [MATH_{0046}], the ’ 1’ tough resin exhibited low dispersion in mechanical properties. The cured resin demonstrated approximately a 1-fold increase in yield strength compared to the uncured state [MATH_{0047}]. This study focuses on the octet lattice structure that is widely employed in current engineering applications.

The load was recorded using a %& a+ pressure sensor from Shenzhen Wance Company [MATH_{0049}], with the loading speed set to &*1 99X9;?%.

Results and Analysis

The compression stress-strain curves for both cured and uncured octet lattice structures at two relative densities are shown in Figure 2 [Figure 2: see original paper]. Figure %# illustrates the true stress-strain curves of the ‘1’ tough photosensitive resin before and after curing ,;@*%#]KC-D-?>;)->DK-»/>DK:;? FCKS-(R’ 1 D(C@O K->;? R(KC?FCK-E :?E FCK-E 橾 d3 % @*CA.

The relative density of the octet lattice structure was calculated using Equation!!” from reference’ %([MATH_{0050}]. Both cured and uncured specimens exhibited approximately a !*1-fold increase in compressive modulus [MATH_{0051}], consistent with literature reports. Figure 3# depicts the relationship between elastic modulus, compressive strength, and relative density ,;@*3#_-):D;(?>O;T .-DZ-? -):>D;F9(EC)C> F(9TK-»;S->DK-?@DO :?E K-):D;S-E-?>;DQ.

This study defines dimensionless normalized stiffness as JDD2J% "( )4 [MATH_{0052}] to [MATH_{0053}]. The relationship between stiffness, dimensionless normalized strength, and relative density is presented in Figure 0 [Figure 0: see original paper]. Both cured and uncured dimensionless normalized stiffness increase with relative density, with cured specimens showing a more pronounced upward trend [MATH_{0054}]. At a relative density of %1i [MATH_{0055}], both cured and uncured dimensionless normalized strength also increase with relative density [MATH_{0066}], with cured octet lattice structures maintaining dimensionless normalized strength above %.

The unit absorption energy data show that both cured and uncured octet lattice structures exhibit increased energy absorption with relative density, but the cured structures demonstrate a significantly higher rate of increase [MATH_{0057}]!& & &*%3! W &*!1" 2 &*1[MATH_{0058}]. The unit absorption energy of cured structures surpasses that of uncured structures [MATH_{0059}], with the disparity becoming more pronounced at higher relative densities [MATH_{0060}]. This enhancement results from the combined effects of increased relative density and UV curing, which improve the elastic modulus and compressive strength of the octet lattice structures [MATH_{0061}], thereby achieving superior energy absorption performance. In summary [MATH_{0062}], UV-cured structures offer lighter weight than the base material [MATH_{0063}] with enhanced energy absorption characteristics, making cured '1' tough resin octet lattice structures highly promising for future applications in aerospace, vehicle and shipbuilding, marine engineering, and related fields [MATH_{0064}].

Unit volume energy absorption was calculated using Equation!2"[MATH_{0065}], with the relationship between unit volume energy absorption and relative density for both cured and uncured structures shown in Figure W. The deformation process involves two distinct stages: a crushing stage followed by a densification stage [MATH_{0066}]. With increasing relative density [MATH_{0067}] 020/ [MATH_{0068}].

Conclusion

%&& [MATH_{0009}] 23!! X2" &!& "/!%0* ' " (#State Council of the People' s Republic of China, Notice on Issuing "Made in China %&%1+" [MATH_{0069}] 1/&1/ [MATH_{0070}] 1/&1 X [MATH_{0071}] & (G8MG [MATH_{0072}] Y G U*U(9TK-»;(? .-O:S;(K>(R!c TK;?D-E TQK:9;E:)):DD;F-DKC»F(9T(>;D->DKCFDCK->' 6(* U(9T(>;D->DKCF/ DCK-> [MATH_{0073}] %!!& [MATH_{0010}].

References

(Ding Li [MATH_{0074}], Xie Weihua [MATH_{0075}], %&%& [MATH_{0076}] ” &03/W2*! cb+M ^; [MATH_{0077}] 7b8P-;OC: [MATH_{0078}] %&%& [MATH_{0079}] ” &03/W2! ;? UO;?->-*” ” ’ [MATH_{0080}] Zhao Yu [MATH_{0081}] et al., “Effect of Porous Structure on Mechanical Properties of ’ -K(PO;D- Type Photosensitive Resin,” *Journal of Northeastern University (Natural Science Edition)* [MATH_{0082}] ” [MATH_{0083}] NYHIGC [MATH_{0084}] -D:)*8RR-FD(R T(K(C»DKCFDCK-(? 9-FO:?;F:)TK(T-KD;->(RS-K(ZO;D-TO(D(>-?>;/ D;S-K->;?' 6(* 6(CK?:)(R+(KDO-:>D-K? ?;S-K>;DQ! ?:DCK:)>F;-?F- ” [MATH_{0085}] ” [MATH_{0086}] !(Gao Dongming [MATH_{0087}] Hu Jing [MATH_{0088}] %& [MATH_{0089}] ! [MATH_{0090}] PH+M7;:?@E(?@ [MATH_{0091}] -D:)*8RR-FD(RF-))>T:F-):DD;F- E;?@S-K>C»DK-DFO;?@E(9;?:D-E :KFO;D-FDCK->' 6(* HFD:9:D-K;:);: [MATH_{0092}] / “3*! M\7;:(FOC? [MATH_{0093}] %&& [MATH_{0012}] 1!%” &” [MATH_{0094}] L G:E(?@ [MATH_{0095}] -D:)*HTT);F:D;(? R(K !

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Note: Figure translations are in progress. See original paper for figures.