THE IMPACT BEHAVIOR OF TETRAHEDRAL TRUSS LATTICE STRUCTURES

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Summary The present work investigates the mechanical behavior under impact loading of 3003-O aluminum alloy tetrahedral truss lattice structures. Quasi-static and impact tests (using large diameter nylon SHPB) are performed on the lattice structures and the results reveal a significant peak force enhancement. Additional tests on the base materials (3003-O alloy) proved however its rate insensitivity. In order to understand the origin of this lattice structure peak force enhancement, the high-speed camera is used to record the deforming mode of lattice structure. Quantitative measurement based on the edge detection algorithm is developed and applied to detect the deforming profiles the beams. It shows that the buckling or significant bending point differs under quasi-static and impact loading and the beam is further compressed before bending under impact loading. The combined effect of this bucking delay and strain hardening leads then to this observed peak force enhancement. Numerical results confirmed this reasoning.

TETRAHEDRAL LATTICE STRUCTURES AND THEIR IMPACT STRENGTH ENHANCEMENT

The present work investigates the mechanical behavior under impact loading of 3003-O aluminum alloy tetrahedral truss lattice structures used as core material in sandwich panels. The tetrahedral truss core sandwich panels (manufactured by Tsinghua University) are composed of two face sheets and the cores sandwiched between these sheets. The core is comprised of three struts or beams which cross together as a regular tetrahedron (as shown in Figure 1) with the beams 15.31mm in length, 2 mm in width and 1 mm in thickness. The height of the core is then 12.5 mm while the thickness of the face sheets is 1 mm. As a result, the relative density of the core is 3.6%. Three sizes of specimens are cut for the investigation of the impact response, one core, three cores, and six cores, as indicated in Figure 1 as well. The specimens both the face sheets and the cores are manufactured from aluminum 3003-O with density 2730 Kg m^{-3}.

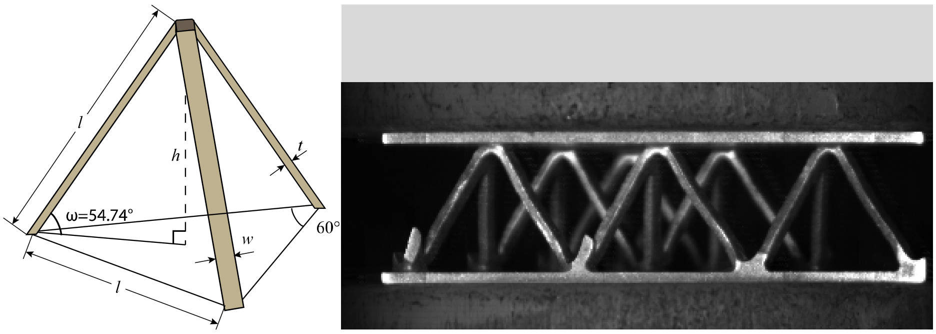

Figure 1: The tetrahedral truss core specimen: basic structure (left) and sandwich (right)

The tetrahedral truss core structures compressive tests are performed under quasi-static loading and impact loading. The quasi-static loading is executed on MTS 810 material testing system. The specimens are loaded at the rate of 0.025 mm/s, which ensures that the nominal strain rate (loading rate divided by the length of the core) is 2×10^{-3} s^{-1}. The impact loading is executed on the Nylon Hopkinson bar with the projectile speed about 12 m/s, which ensures that the nominal strain rate is 10^3 s^{-1}. Testing results of 6 cores specimen in Figure 2a shows an obvious increase of the peak force from quasi-static loading to impact loading. It is noted that there is no notable size effect in both dynamic loading and quasi-static loading and the average increase is about 20%. Meanwhile, quasi-static and dynamic uniaxial tensile experiments of the base material have been performed on Instron 5882 testing system and 10 mm diameter Hopkinson tensile bars separately. The strain rate ranges from 10^{-4} s^{-1} to 10^2 s^{-1} and a weak rate-sensibility of the base material Al3003-O is found (Figure 2b).

HIGH SPEED PHOTOGRAPHY, EDGE DETECTIONS, DEFORMING PROFILE OF BEAM

It is known that the lateral inertia may cause a significant strength enhancement in a buckling problem [1-2]. It could be the origin of this puzzling lattice structure peak force enhancement. In order to get an inside look, a high-speed camera is used to record the deforming sequence of lattice structure. Under quasi-static loading, Canon EOS 50D is used in the acquisition frequency 0.5 frames per second (fps). Under impact loading, high speed camera Photron SA5 is used to shot the images of 384×160 pixels at 100 000 fps while the aperture value f5.6 and the shutter speed 1/151000 s assure the sharpness of the images[3]. Due to the two powerful cold spotlights, the images are ensured to a correct contrast in despite of the small aperture and high shutter speed. Quantitative measurement based on the Canny edge detection algorithm [4] is developed and applied to detect the deforming profiles the beams. Figure 3a,b illustrates the results of detected deforming profiles at different moments. The length of the beam is summed up all the Euclidean distance between two adjacent edge points. The evolution of the length during loading is plotted in Figure 3c. It illustrates the beam length reduces rather linearly at the early stage and stay nearly constant afterward. Such a measurement can be interpreted as the compression of the beam is rather constant at early stage of loading before bending becomes dominant.

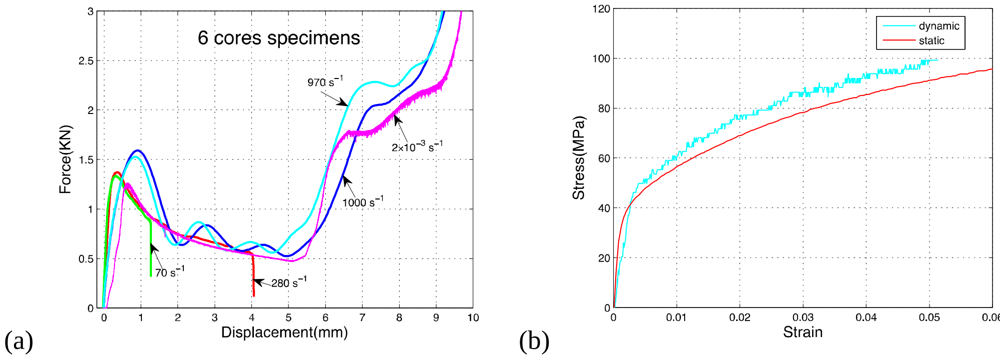

Figure 2: Testing results of sandwich structures (a) as well as its base materials (b)

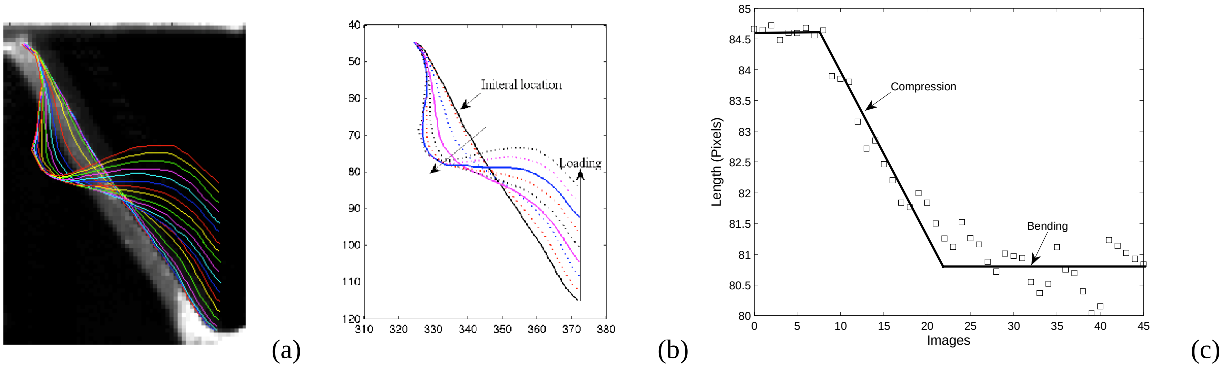

Figure 3 Detection of deforming profiles of struct : (a)images (b) detected profiles (c) length evolution

BUCKLING DELAY, STRAIN HARDENING, PEAK FORCE ENHANCEMENT

Such a length measurement reveals that the buckling or significant bending point differs under quasi-static and impact loading and the beam is further compressed before bending under impact loading. For a given sandwich global crush of 1.2 mm, the quasi-static nominal axial strain is about 1.4% while the impact one is 3.4%. The experimental stress-strain curve in Fig.2b indicates that the strength of base material Al3003-O increase about 30% when the strain increase from 1.4% to 3.4%. Thus, the combined effect of this bucking delay and strain hardening leads then to this observed peak force enhancement. Numerical results confirmed this reasoning (Fig.4)

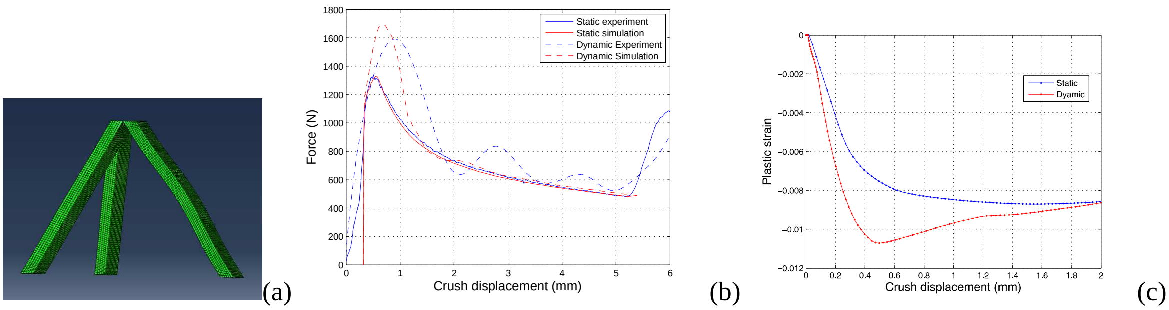

Figure 4: Numerical models (a) comparison between tests and simulation (b) plastic strain(c)

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